American Academy of Maxillofacial Prosthetics Meeting, Philadelphia, Pa., Oct. 11 to 13, 1961.

American Denture Society Meeting, Philadelphia, Pa., Oct. 13 and 14, 1961.

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VOLUME 11 SEPTEMBER-OCTOBER, 1961 NUMBER 5

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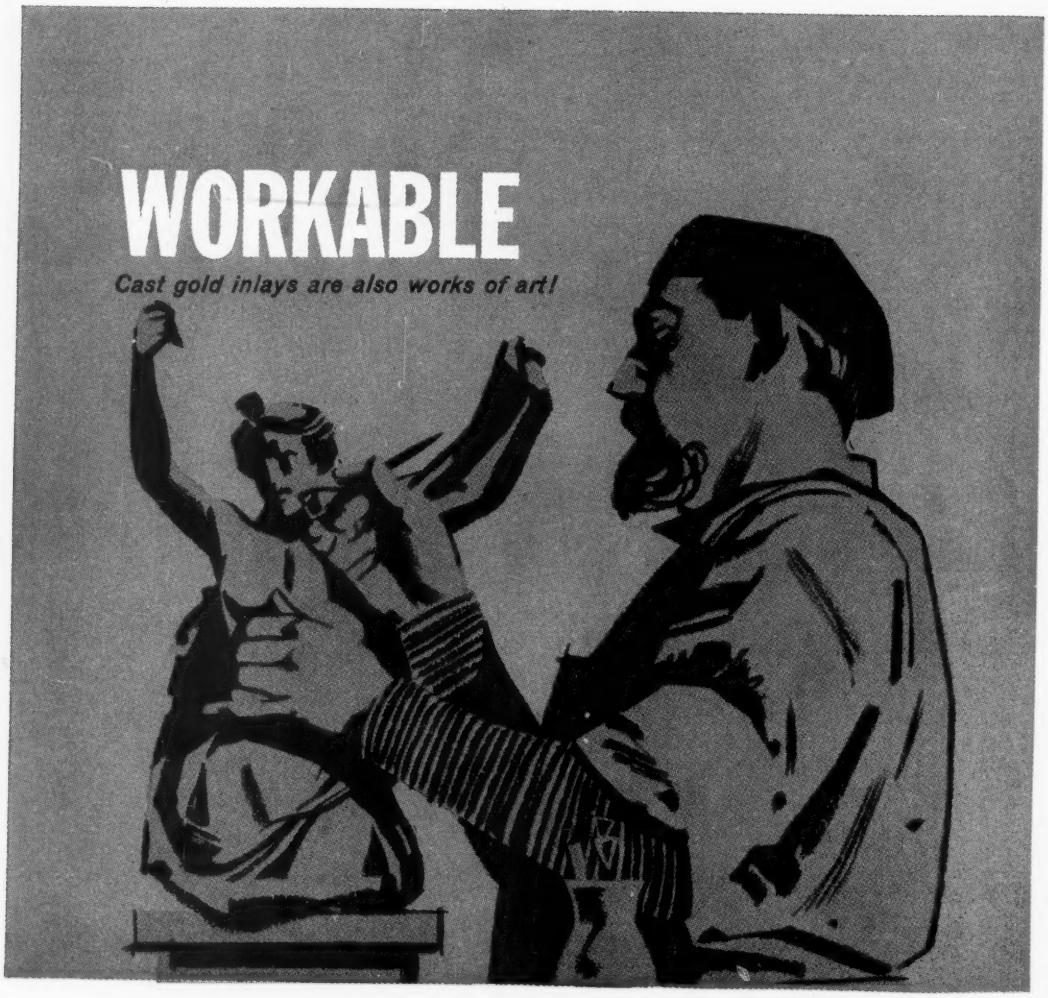

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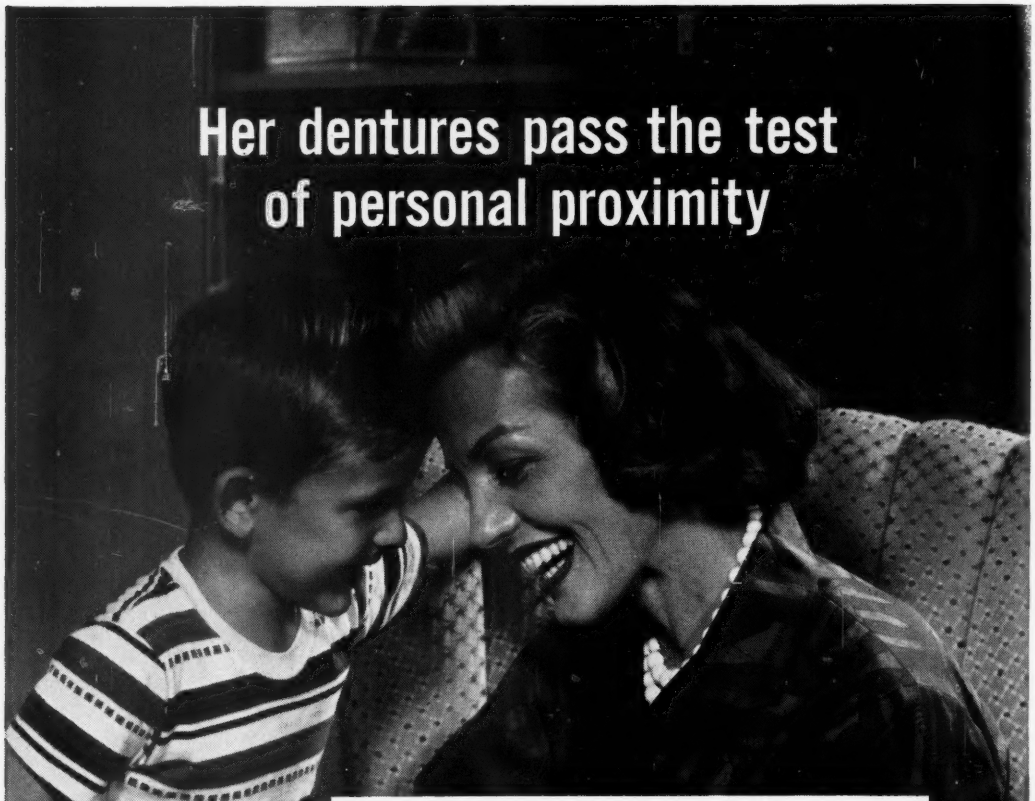

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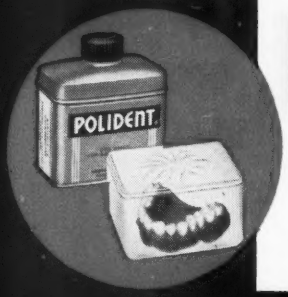

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Claude R. Baker, B.A., M.S., D.D.S., University of Kansas City, School of Dentistry, Kansas City, Mo. **929**

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OPERATIVE DENTISTRY

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F. A. Peyton, D.Sc., and Elena L. Liatukas, D.D.S., M.S., University of Michigan, School of Dentistry, Ann Arbor, Mich. **934**

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Louis G. Terkla, D.M.D., David B. Mahler, Ph.D., and John C. Mitchem, M.S., University of Oregon Dental School, Portland, Ore. **942**

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O. W. Rogers, B.D.S., and B. W. Armstrong, A.S.T.C. (Chem. Eng.), A.R.A.C.I., Sydney, Australia **959**

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William H. Dietz, D.D.S., Ohio State University, College of Dentistry, Columbus, Ohio **967**

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Harry Rosen, D.D.S., McGill University, Montreal, Que. **973**

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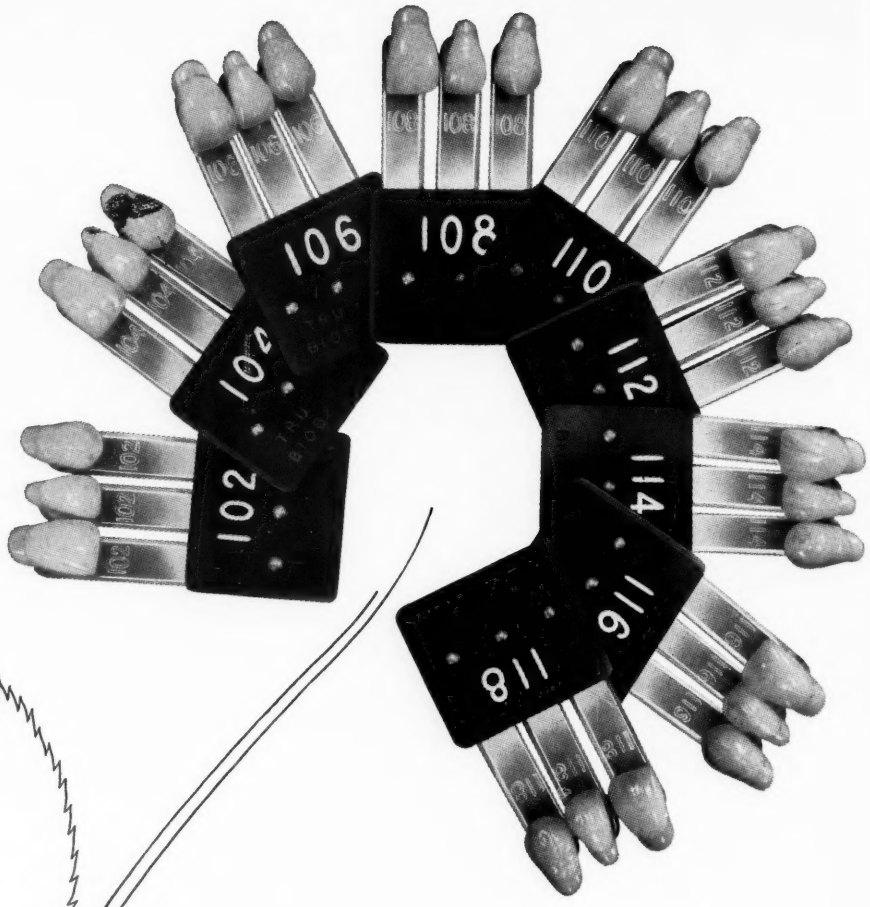

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THROUGH THE EYES OF THE EDITOR

Wilson W. Chase discusses the health of oral mucosa under dentures and suggests a means for restoring irritated tissue to health. He uses as a treatment material a soft plastic resin that conforms to the shape of the oral tissues and tends to stimulate or massage them in function. He found considerable improvement of the health of the oral mucosa but reports no comparison after treatment with the condition if the dentures had been left out of the mouth for a while. Tissues recover rapidly when the dentures are not worn and probably assume their correct, healthy form. The method of treatment, however, is not as important as their being made healthy. Many dentures fail because the impressions are made of tissues that were distorted by the old dentures. The same error is committed when dentures are relined without adequate rest or treatment for the tissues.

E. C. Kelly Geiger describes his procedures for relining dentures. The technique involves new impressions and jaw relation records so the dentures can be reoriented on the casts on the articulator. To reduce laboratory time, he uses self-curing acrylic resin on an articulator held in closed position by C clamps. The occlusion is perfected on the articulator before the dentures are removed from the casts.

Joseph S. Landa discusses the relation of deglutition to the masticatory system and reports his studies of the anatomy and physiology of the parts involved. He found that some occlusal disharmonies can cause difficulty with deglutition, respiration, and phonation. He questions the extant theories regarding passage of food through the pharynx and urges new approaches for the study of this phenomenon.

Dayton D. Krajicek, Philip M. Jones, Stanley F. Radzyminski, Donald L. Rose, and Eugene Unti report their comparison of a physiologic method for determining the physiologic rest relation with an electromyographic method. The vertical dimension was first determined by measuring between two arbitrary facial points when the mandible was thought to be in rest relation. The active electrode of the electromyograph was placed on or in the masseter muscle to detect any activity. They assumed that the minimum electrical activity represented rest position. They found a good correlation of the measurements obtained by the clinical and electromyographic methods. They point out that judgment is a factor in the clinical method, but that it is a practical and reasonably reliable method.

Frank L. Basler, James R. Douglas, and Robert S. Moulton report their studies of three techniques for determining the vertical dimension of occlusion. They compared the results of a number of dentists and used cephalometric roentgenography to evaluate these. The vertical dimension of occlusion with natural teeth was accepted as correct. They found a tendency toward a decreased vertical dimension with all of the techniques and could not select one method as being the most nearly accurate.

Louis Boucher and Jay Jacoby report their investigation of the posterior border movements of the mandible. They made needle point tracings of mandibular movement in the horizontal plane and found the mandibles of 11 of 12 subjects could be moved further posteriorly with general anesthesia. They conclude that muscles rather than ligaments stop posterior movement of the condyles in the fossae. The amount of force used during recording was not given, and it is possible that more external force was applied under anesthesia than the subjects applied while conscious. If centric relation is recorded at the most posterior position that can be recorded while the patient is conscious, it would seem to cover clinical requirements.

Honorato Villa A. discusses occlusion and concludes that currently accepted principles need revision. He suggests the guidances on most articulators are incorrectly placed on the upper part, when they should be placed on the lower member. He states that inaccuracies in occlusion result from the incorrect design of the articulators. The physical principle that all movements are relative seems to be involved. If this is true, it should make no difference where the guides are placed, so long as the instrument can be adjusted according to the interocclusal records made in the mouth.

Firoze D. Mirza reports his studies of dimensional stability of acrylic resin dentures. Comparing heat-cured and cold-cured dentures in laboratory and clinical tests, he found dimensional changes in both types in curing and subsequent dimensional changes in up to 3 months of use. Even though the cold-cured dentures shrank throughout the test period, this change did not have a significant effect on their fit.

Vincent R. Trapozzano and John B. Lazzari located the hinge axis points and attempted to find alternate ones in 14 subjects. They found multiple hinge axis points on one or both sides in 57.2 per cent. They question the reliability of hinge axis determinations as used in clinical practice. The results may also indicate the technical difficulty involved.

Lowell H. Body describes his technique for relining immediate dentures. He uses cephalometrics for determining the vertical dimension and for reorienting the occlusal plane. The procedure takes into account the many alterations in denture position which may not be recognized by simple refitting of dentures to the supporting structures.

Albert Zola and Eugene A. Rothschild report their studies of the condyles at rest position and in other mandibular positions assumed during unimpeded jaw movements. Their results indicate no predictable relationship between the location of the condyle at the hinge axis position and at physiologic rest. They found identical hinge axis positions of the condyles when the patient moved the mandible back and when the dentist manipulated it. They conclude that not all premature contacts are deflective and destructive. Apparently, in this they were considering the effect on the temporomandibular joints and not on the periodontium.

Oliver C. Applegate discusses evaluation of oral structures for removable partial dentures and points out the critical diagnostic factors involved. These are practical applications of the basic sciences which make it obvious that one with less training than a dentist would be incapable of designing a partial denture correctly. The real design of a partial denture is determined by evaluation of the bone, soft tissues, and occlusion in the mouth and *not* on a cast. He points out the need for adequate directions to, and technical excellence of, the dental laboratory technician. However, the success of the restoration depends primarily upon the accuracy of the dentist's diagnosis and design.

Clare W. Sauser discusses pretreatment evaluation of partially edentulous patients and suggests a logical procedure for diagnosis and treatment planning. He states that more failures result from incorrect planning than from technical inadequacy. This emphasizes the dentist's responsibility and the fact that, regardless of his skill, the technician does not have the necessary background for diagnosis or design of prosthetic restorations.

Joseph S. Frost suggests that distal extension partial lower dentures be made so that all available soft tissues are covered with denture-base material. This includes the tissue lingual to the anterior teeth. He covers the metal lingual bar with plastic, which is allowed to contact the soft tissue. This gains support from the bone on the lingual side. This transfer of force should be helpful until settling of the distal ends of the denture base occurs. Then it could cause destruction of bone lingual to the remaining teeth if allowed

to continue pressing forward against these tissues. Of course, if the bases did not settle, this disadvantage would not apply.

Angelo D'Amico discusses the functional occlusion of the natural teeth of man, starting with analysis of primitive occlusions. He found evidence of a significant protective function of the cuspid teeth in these occlusions and bases his concept of occlusion of restorations of natural teeth on this function. He points out an important difference between the ideal occlusion of dentitions and complete dentures. He suggests that if the natural developmental factors are recognized, many teeth lost because of periodontal disturbances could be saved. This involves the elimination of deflective occlusal contacts in many natural occlusions and a modification of eccentric occlusions to avoid trauma in eccentric occlusal function.

Dwight K. Shellman describes his technique for a fixed partial denture in a one piece casting. He feels that many teeth are not replaced by fixed restorations because of the pressure of time. His technique permits maximal use of auxiliary personnel. The technique requires the ultimate in skill and in accuracy of controlling the shrinkage of gold.

Leonard I. Linkow discusses the selection of abutments for full mouth splinting and suggests means for saving teeth which would be lost otherwise. He lists the basic qualifications for abutments and the exceptions which may apply. Full arch splinting is a radical treatment if the abutments are questionable, so good clinical judgment is essential.

George T. Cowger and Felix F. Woycheshin suggest plating gold castings to which porcelain is to be baked. Only the surface of gold over which the porcelain is placed is plated. This provides a uniform yellow background for the porcelain and should simplify the problem of color consistency. The possible disadvantage is a lack of union between the porcelain and the gold, but they use extra mechanical retention.

Claude R. Baker describes his technique for adding root forms to dies. The root forms are shaped to be free from undercuts and can be removed from the master cast easily. He lists several advantages of the simple technique.

F. A. Peyton and Elena L. Liatukas report their studies of different condensation forces with various amalgam alloys. They conclude that poor condensation weakened the amalgam and that this is most significant after 1 hour. They also found the compressive strength of the different amalgams tested may vary more than 20 per cent and that not all fine cut alloys have superior compressive strength values.

Louis G. Terkla, David B. Mahler, and John C. Mitchem report their tests on bond strength of repaired amalgam. They found that it is less than half the strength of unrepaired amalgam and that the bond is weaker as the original amalgam is older. Their results indicate that the repair of amalgam fillings is hazardous.

Myron E. Warnick and Kenneth N. Morrison describe their technique for porcelain inlays. They use a rubber-base impression to make a mold in a refractory investment resistant to high heat. This makes a platinum matrix unnecessary and greatly simplifies making porcelain inlays.

O. W. Rogers and B. W. Armstrong describe an indirect inlay technique in which the die is electroplated with gold and the wax pattern is formed in the gold matrix. The layer of pure gold permits burnishing not possible with most casting golds.

William H. Dietz describes modified preparations and means of retention for restoring mutilated teeth. These techniques could save many teeth that have been considered hopeless. His modifications may be used for gold or amalgam restorations.

Harry Rosen discusses the restoration of endodontically treated teeth and describes several procedures for reinforcing the roots. He suggests the use of crutches (cast posts) and braces (crowns with collars to prevent splitting). If pulpless teeth are fitted with these restorations, their usefulness and longevity will be increased. The technique is not difficult, and it appears to be effective.

W. Arthur George discusses the use of elastic splints to assist in the control of bleeding after tooth extraction in hemophilic patients. His technique appears to be simple and effective.

—Carl O. Boucher

COMPLETE DENTURES

TISSUE CONDITIONING UTILIZING DYNAMIC ADAPTIVE STRESS

WILSON W. CHASE, B.S., D.D.S.*
Los Angeles, Calif.

THE CONCEPT of oral mucosa conditioning is gaining momentum as dentists become aware that conditioned tissue will support a denture more comfortably and that alveolar bone is thereby probably preserved.[1] The concept is not new. For years, dentists have advised patients with sore mouths to leave their dentures out until the tissues have recovered to a normal, comfortable condition. Schultz[2] relines the denture with wax and allows the patient to wear it a few hours before rebasing. Skinner† reduces hypertrophic tissue by having patients chew an inflated plastic bag with the edentulous ridges.

Lytle[1,3] demonstrated that alveolar bone is resorbed beneath restricted areas of excessive denture pressure and that new bone forms in these same areas when a new denture is made to fit conditioned mucosa. He focused attention upon deformed and irritated mucosa beneath dentures which causes discomfort and suggested conditioning procedures utilizing fast-setting impression materials.

This article is a report of a clinical study of (1) conditioning of the mucosa by the continuous stress of force and motion transmitted to the basal seat tissues through occluding dentures by a resilient, flowing treatment material and (2) use of the completed treatment impression as a final dynamic impression. This action is called dynamic adaptive stress.

The study was inspired by, and is a corollary to, Lytle's thinking.[1,3] However, the addition to his concept is that the force or pressure of denture occlusions and the movements of the mandible are used continuously and progressively to condition the oral mucosa. Too, the patient wears the dentures normally during all of the conditioning period.

Under certain circumstances, the denture lined with treatment material is used for the final impression either for relining or for a new denture. The patient may wear the treatment dentures while new dentures are fabricated.

Read before the Academy of Denture Prosthetics in San Juan, Puerto Rico, and the Pacific Coast Society of Prosthodontists in Santa Monica, Calif.

*Dental Service, Veterans Administration Center, and Associate Professor of Prosthodontics, University of Southern California, School of Dentistry.

†C. N. Skinner: Personal communication.

Fig. 1.—A cold-curing acrylic resin base with an impression plastic rim is used to carry the treatment material when the old denture is inadequate.

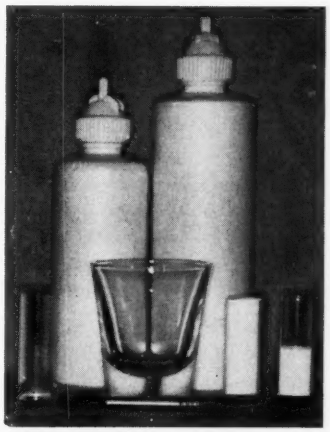
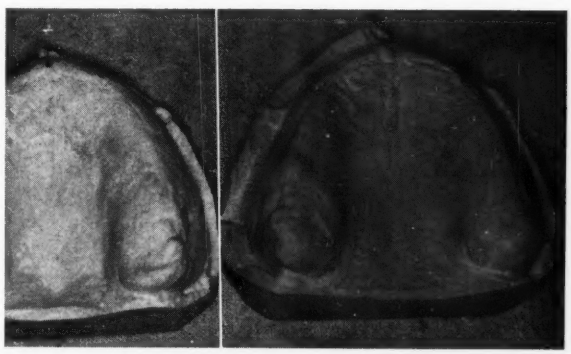


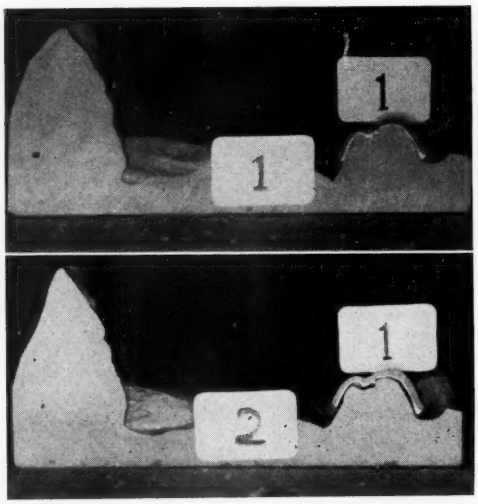
Fig. 2.—The tissue treatment material is prepared by mixing 1 part of liquid with 1½ parts of powder.



A. *B.*

Fig. 3.—*A*, A diagnostic cast of a patient who wore dentures for 5 years before mucosal conditioning. Note the flattened, deformed rugae and incisive papilla and the groove made by the denture on the left tuberosity. *B*, A diagnostic cast made after 4 days of mucosal treatment. Note the elevated rugae and incisive papilla and the disappearance of the groove on the left tuberosity.

A.



B.

Fig. 4.—A baseplate *(A)* made for an unconditioned ridge *(1* on cast *1)* will not fit the ridge after mucosal conditioning *(B) (1* on cast *2)*

When the dentures are inadequate to carry the treatment material, acrylic resin denture bases are fitted with impression plastic rims that are adjusted to the proper vertical dimension of occlusion (Fig. 1). The patient wears the denture bases in lieu of dentures as much as possible. Most patients are able at least to mash soft food with them.

According to Webster, the word condition is an intransitive verb meaning "to attain a proper or fit condition." Treatment of the oral mucosa does lead to attainment of "a proper or fit condition" of it, which is interpreted as a normal condition and contour that will support a denture comfortably in dynamic and static functions; dynamic means the forces producing or governing activity or movement of any kind.

Five prosthodontists and six general dentists contributed experiences to this report. The tissue-conditioning material was used in 343 dentures or substitute denture bases with occlusion rims. Two-thirds of the patients were men averaging 62 years of age, treated by the author. The other ten dentists used the material for both men and women of an undetermined average age.

CHARACTERISTICS OF THE CONDITIONING MATERIAL

The conditioning material* is prepared by mixing a white acrylic resin powder with a colorless, clear, somewhat oily liquid plasticizer having an odor of alcohol (Fig. 2). The mixture begins to gel immediately. In 10 minutes, it is a cohesive, resilient mass. The material flows continuously under pressure at a rate inversely proportional to time, becoming stiffer but never losing its resiliency. A denture

*Hydrocast.

lined with the conditioning material loosens somewhat after 72 hours but remains comfortable and retentive. The material discolors and becomes grainy when the denture is worn for many weeks.

Most patients assess the conditioning material to be tasteless, odorless, and nonirritating. Three patients said it spoiled the taste of food, and a few said it felt slightly warm for a few minutes after insertion. The material does not adhere to wet mucous membrane, but it does adhere to dry skin, dry acrylic resin, and to itself. It is easily removed from skin after curing or before curing by wiping with gauze wet with orange solvent or chloroform. The material may be removed from acrylic resin with a scraper or a dull denture bur.

The manufacturer states that the conditioning material exerts about the same pressure on the tissue as the diastolic blood pressure. There is no proof of this, however it would seem to be a valuable property. Empirically, it could be true, because the oral tissues do assume a different contour under treatment (Figs. 3 to 5). We assume it is beneficial. The material is adequate for making impressions as defined by Boucher[4] and Roberts.[5]

METHOD OF STUDY

Three procedures were adopted to study the force and motion concept and the potentialities of the material for accomplishing mucosal conditioning and making dynamic impressions. The material was used (1) in an old or new denture for

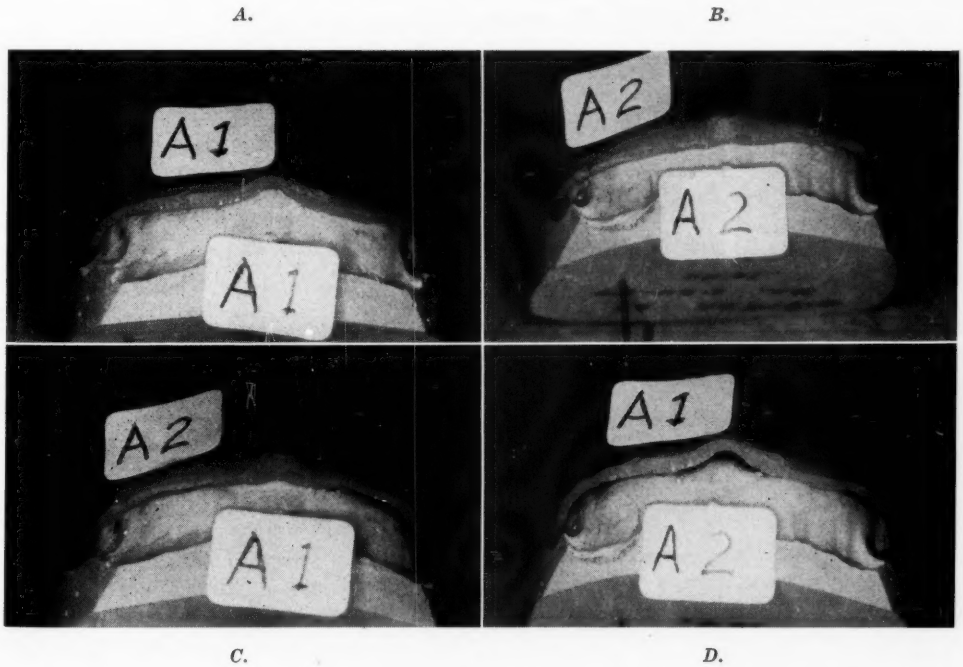


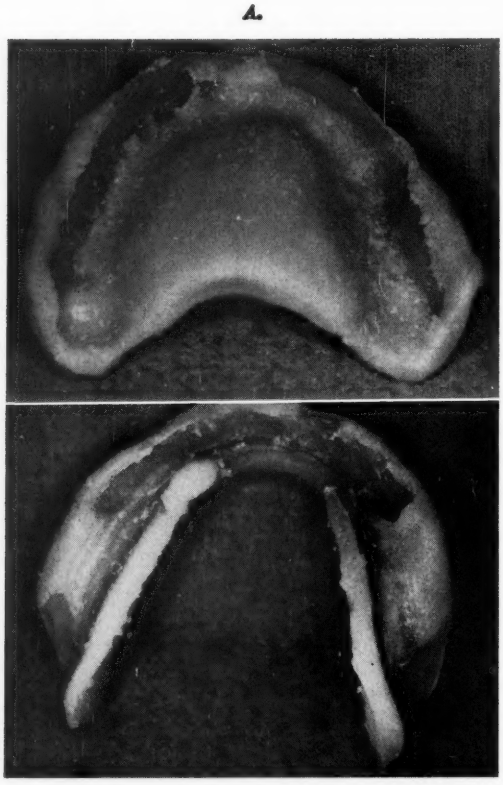
Fig. 5.—*A*, A well-fitting baseplate *(A 1)* on a cast *(A 1)* made before mucosal conditioning. *B*, Baseplate *A 2* on cast *A 2* made after 10 days of mucosal conditioning. *C* and *D*, The baseplates are transferred to the opposite casts. Note the differences in the mucosal contours.

mucosal conditioning and to obtain a dynamic impression for relining, (2) in an old denture or an acrylic resin denture base with occlusion rims for mucosal conditioning and to obtain a dynamic impression for a new denture, or (3) in a nonrebasable denture or an acrylic resin denture base with occlusion rims for mucosal conditioning only, followed by the usual impression procedures with nonresistant materials.

THE TECHNIQUE

Dentures must be properly prepared for the successful use of the treatment material. Border overextensions must be reduced. Underextensions must be built up with impression plastic or cold-curing acrylic resin. The material must be supported close to the tissue reflection, especially where the border is thin. The impression surface of the denture must be clean and dry so the material will adhere to the resin.

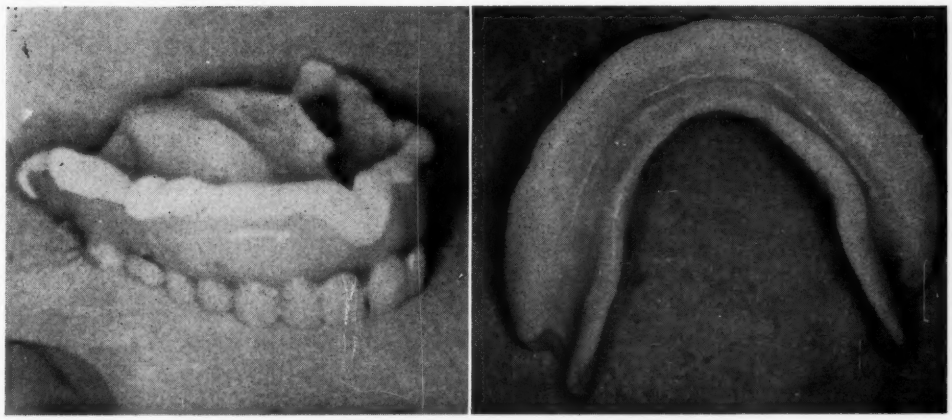
The tissue surface of the denture should be ground out to a depth of 1.5 mm. to make space for the material when it is essential that the vertical dimension of occlusion must not be increased. Gross occlusal disharmonies must be corrected.



A.

B.

Fig. 6.—Pressure areas or overextended borders which show through the treatment material are cut away with a denture bur.



A. *B.*

Fig. 7.—Impressions completed by dynamic adaptive stress using the treatment material. The impressions are considered to be complete when, after wearing them a few hours, the patient states that the dentures feel the way he wants them to feel. Casts can be poured into these impressions for making new dentures or for relining.

If the denture is to be relined, it may be necessary to remount the dentures on the articulator and correct the occlusion.

In complete dentures, the material is placed and formed in the upper denture first so it will control the position of the lower denture. The material is poured into the upper denture immediately after mixing and is distributed evenly over the tissue surface and borders with a cement spatula. To prevent forward movement of the denture, no conditioning material is placed on the impression surface of the labial flange. The upper denture is seated when the material begins to flow sluggishly.

The lower denture is placed in the mouth, and the patient is instructed to tap the teeth lightly together to position the upper denture. Heavy tapping or closure with force will squeeze out too much of the material. During the preliminary polymerization, further seating and border molding are promoted by having the patient draw lightly on the dentist's finger, as in smoking.

In 10 minutes, the material has polymerized sufficiently so that the lower denture may be removed, prepared, loaded with material, and seated by tapping the teeth together lightly. Border molding is accomplished by thrusting the tongue into the cheeks and out of the mouth, grimacing, pouting, swallowing sips of water, talking, or reading aloud.

In another 10 to 15 minutes, both dentures are removed. Excesses of material around the borders are removed with a knife or scissors. Pressure spots and overextended borders denuded of material are reduced with a denture bur (Fig. 6).

Three procedures may be used for repair of the conditioning material. New material may be patched in, a second layer may be added, or all of the material may be removed and replaced. Rough borders are covered with a thin mix of the material carried on a sable brush and are remolded smooth in the mouth. Wrinkles or voids are repaired in the same manner. The patient is dismissed for 2 or 3 days with instructions to continue his normal denture use and cleanliness.

When the patient arrives for his second appointment, he usually states that the mouth is more comfortable and the dentures fit better. However, he still may have a sore spot or two, or the teeth feel higher on one side. In every instance, an examination of the denture revealed the patient was correct. Wherever he indicated soreness or pressure, the denture had been denuded of the conditioning material. Pressure spots are burred out and repaired by patching, adding, or total replacement.

Ultimately, whether it is the second, third, or perhaps the eighth treatment appointment, the patient declares his dentures are comfortable beyond belief. They exhibit stability and retention. Examination reveals the tissue surface of the denture is completely covered with the material although it may appear to be thin in some places. There are no pressure or sore spots on the mucosa that may be detected either subjectively or objectively.

The conditioning material is removed and replaced, and the patient returns in 48 hours for the final treatment. The final procedure entails spreading a thin mix of the material with a sable brush all over the new material which was placed 48 hours before. After this mix has cured for 10 to 15 minutes in the mouth, the denture is removed. Defects, wrinkles, voids, or underextensions are repaired by

TABLE I

DETERMINATION	DAYS BETWEEN TREATMENTS	TOTAL DAYS FOR CONDITIONING
Average	3.3	7.8
Minimum	1	3
Maximum	8	23

brushing in a small amount of powder with a sable brush wet in the liquid. Additional liquid is applied with the brush to smooth the added material.

The patient is dismissed with instructions to return when the dentures feel best. Most patients do so in 4 to 5 hours. The least time on record is 2 hours and the most 23 hours. The patient is reminded that he has noticed his dentures have felt best a few hours after each treatment and then started to loosen about the second or third day. The decision about when the denture feels best is left to the patient. He is told that his relined dentures will fit just like the treatment denture does when he delivers it to the dentist for processing (Fig. 7).

A cast is poured in the denture before the material dries, and as soon as possible, the denture is mounted on the articulator and a stone core is made for correctly positioning the teeth.

If a new denture is to be made, the cast may be used for it, and then the treated denture is given back to the patient to wear until the new dentures are completed. If new impressions are to be made in other impression materials, the final placement of the thin layer of treatment material is omitted.

After using so much care in conditioning the tissue, the best possible techniques should be used for processing the dentures.[6]

RESULTS

The number of days between each treatment and the total number of days required to complete the conditioning are shown in Table I. The number of treatments required are shown in Table II.

TABLE II

DETERMINATION	NUMBER OF TREATMENTS	
	MAXILLAE	MANDIBLE
Average	3.5	3.7
Minimum	1	2
Maximum	6	8

A record of the necessary adjustments was kept on forty-four dentures made without the use of conditioning material for patients with average conditions and on 343 dentures made using the conditioning material as part of the treatment for patients with difficult or unfavorable conditions. Table III shows the comparison.

After mucosal conditioning, the patients with unfavorable conditions required a similar number of denture adjustments as the more favorable, routine patients. A little less than half of the difficult patients needed adjustments, and among those,

TABLE III

NUMBER OF DENTURES	PERCENTAGE NEEDING ADJUSTMENTS		ADJUSTMENTS PER DENTURE	
	MAXILLARY	MANDIBULAR	MAXILLARY	MANDIBULAR
44	5	59	1	2
343	36	48	1	1.5

each denture required about 1.5 adjustments. These figures were about the same for all dentists participating in this study but were slightly less favorable for the prosthodontists. This is to be expected since the prosthodontist works with a higher percentage of difficult patients.

The original complaints of the patients prior to conditioning, in decreasing numerical order, were soreness, general discomfort, loose dentures, and inability to

eat. Many patients had endured these conditions with several dentures over periods of up to 30 years. The necessity for adjustments of dentures worn after treatment was caused, in decreasing order, by the impression, the occlusion, and curing, in a ratio of about 4 :4 :1.

There was little difference in the conditioning and impression results obtained by the different methods with one exception. When new dentures were made from the dynamic impression produced with the denture base fitted with occlusion rims, the number of individual denture adjustments was 20 per cent above the average. This may indicate that superior impressions are produced by the force and motion delivered to the supporting tissues by the occlusion of teeth.[7]

Nine patients were difficult enough that the dentures made for them were classed as partial failures. The mucosa of 1 patient was conditioned four times, of 1 three times, and of 4 twice. Usable impressions could not be obtained for 3 patients.

An allergic reaction to the conditioning material was reported in 1 patient. The characteristics were a red mucosa and constant burning. Immersing the treated denture in weak hydrochloric acid for 15 minutes alleviated the condition.

Five mandibular removable partial dentures were prepared for relining by tissue conditioning. The casts were poured in the impressions. Four dentures required no adjustments, and the other denture never became comfortable because the lingual bar was not rigid.

CAUSES OF FAILURE

Nine patients failed to improve to a successful conclusion. One patient was truly psychoneurotic. Another failure was caused by an excessive vertical opening that was not detected until the dentures had been worn a few weeks.

Two other patients had a stormy history of denture wearing. Their dentures were rebased, remade, reconditioned, soft lined, and re-equilibrated. We do not know why they still hurt. Perhaps the patients could exert pressures beyond the limits of tissue tolerance with their very efficient dentures.

Two failures resulted from an undetected occlusal derangement. The occlusions appeared acceptable, the treatments progressed satisfactorily, and the treatment dentures were finally pronounced excellent by the patients. When sore mouth and repeated adjustments continued after the relining, the dentures were remounted by the technique described by Lauritzen.* So much error was found that equilibration could not be accomplished. Conditioning treatment in acrylic resin bases with occlusion rims eliminated the soreness. Casts were poured in the impressions, and new dentures were made. These dentures have been satisfactory, with but one adjustment necessary for one of the lower dentures.

The other three failures involved maxillary and mandibular ridges that were excessively resorbed. The rugae area was continuous with a flat palate. The bone of the anterior part of the ridge was at the level of the anterior nasal spine and covered with hypertrophied mucosa. The tuberosities were small. The mandibular

*A. Lauritzen: Personal communication.

ridge was resorbed below the level of the exterior oblique ridge and the genian tubercles so that the denture skidded around as if in a bowl. The alveolar mucosa was detached from the periosteum. When the patient closed the jaws, the upper denture rocked anteriorly on a fulcrum line through the anterior ends of the residual bony ridge in the bicuspid region. Although conditioning could be accomplished reasonably well, a stable impression could not be obtained. New dentures were made for these patients by other techniques.

DISCUSSION

The basic reason for lack of comfort with most dentures is the problem of coordinating occlusion with mandibular movements. Nonpressure impressions, total coverage and stress distribution, metal bases, different kinds of teeth, anatomic articulators, treatment by nutrition, various theories of occlusion, and equilibration by selective grinding are all attempts to solve the problem of comfort.

The many factors blamed for denture sore mouth and bone resorption can be classed as biologic, pathologic, bacteriologic, physiologic, psychologic, anatomic, physical, medicinal, and technical. The concept of tissue conditioning contains elements of stress distribution and occlusion and is classed as physiologic and physical.

Most dentures fail because of inadequacies of diagnosis and treatment planning or because basic principles of fabrication are ignored. Obscure causes for failure may not be revealed until dentures are completed and worn for a few days or even weeks. However, most patients can be made comfortable when the treatment is based on an adequate knowledge of psychology, physiology, and techniques.

The first technical step to make the patient comfortable is an adjustment of the occlusion and placement of the conditioning material in the dentures. The vertical and centric relation records should each be checked and rechecked. Occlusion is the most important factor in denture fabrication and must be handled by a judicious choice of a posterior occlusal scheme that is properly coordinated.

The continuous and simultaneous shaping of the denture basal seat and the impression surface of the denture under the force and motion applied to dentures is a helpful adjunct to the fabrication of more comfortable dentures. Dynamic adaptive stress is not a cure-all for denture difficulties, neither will it compensate for careless and inadequate techniques. Proper handling of the treatment material shortens the period of conditioning, and better impressions are produced.

The handling of the treatment material makes the difference between indifferent success and real success. While the consistency of the material when introduced into the mouth is not too critical, it is best to use proportions of approximately 1½ parts of powder to 1 part of liquid. If the denture is placed in the mouth too soon, most of the material will be squeezed out. Tapping the teeth together too heavily or too great a vertical opening will lead to the same result. If the material is too stiff before the denture is placed in the mouth, its even distribution is delayed. As a result, the flow is sluggish, additional time is required in treatment, and overextension of borders, particularly in the buccal vestibules and labial notches, will require unnecessary adjustments.

A second layer of the material or a patch may be added within a few minutes after the first layer is placed in the denture. However, it defeats the purpose to patch material on a layer that has been worn for 2 or more days, because this may cause areas of local pressure. The building of layer on layer of the material for the purpose of increasing the vertical dimension of occlusion allows undetected pressure spots and overextensions to be developed, and this would increase the number of necessary adjustments.

The importance of a coordinated occlusion cannot be overemphasized. The selection of the occlusal scheme is not as important as the requirement that it be correctly coordinated with mandibular movements. Both the mucosal conditioning and the impressions are improved if they are accomplished in dentures with a coordinated occlusion.

A relining procedure with the treatment material was used on 173 dentures with a coordinated occlusion. The results compared favorably with the average and convinced us that this was an efficient rebasing technique. If desired, new dentures can be fabricated and used to carry the treatment material in the same manner. In this procedure, care should be taken not to increase the vertical dimension of occlusion if it was correct before beginning treatment.

The conditioning treatment was carried out with ninety-six dentures, about half in old dentures and half in denture bases with occlusion rims. Dentures made on casts poured in these dynamic impressions were, in general, superior to those made from our usual impressions. This may indicate that static impressions of unconditioned mucosa cause tissue distortion that is not compatible with functional pressures. Those dentures made from impressions formed in old dentures required slightly less adjustment (1.2) than those made from impressions made in new denture bases with occlusion rims (1.6). This seems to indicate that occlusion of teeth is necessary to conform the impression to the tissue surface in function. Obviously, the pressures applied would differ in force and direction.

In a third test, the conditioning was followed with an impression made by our usual method. Again, the dentures made following dynamic treatment in old dentures required slightly less adjustments (1.2) than those made after treatment in new denture bases with occlusion rims (1.5).

CONCLUSIONS

1. Dynamic adaptive stress promotes a condition and a contour of the denture-base mucosa that are compatible with denture function.

2. The completed treatment impression may provide the base for a final functional impression.

3. A nonsetting material which flows, yet is resistant, is necessary to utilize dynamic adaptive stress.

4. The resulting excellence of comfortable denture adaptation is effective only if other factors of denture fabrication are performed with care. These factors are the recording of jaw relationships, the curing process, and the coordination of the occlusion.

5. The concept of tissue conditioning proved to be useful for converting denture failures to successes. It is hoped that bone preservation will follow.

6. Denture adjustments for difficult patients were appreciably reduced by the use of dynamic treatment, dynamic impressions, and careful techniques. However, the improved results were more subjective and objective than statistical.

7. The treatment material performs its function best if it is completely replaced about every third day. Patching or adding layer on layer is permissible if it is done within a few minutes after the first layer is placed in the denture.

8. The occlusion of teeth apparently was more effective in promoting mucosal conditioning and forming dynamic impressions than were nonfunctional denture bases with occlusion rims.

9. A small percentage of dentures (3 per cent) fell short of perfection. A slightly larger number (7 per cent) were successful only through additional effort such as conditioning more than once or re-equilibrating the occlusion. However, 90 per cent of the 343 dentures observed were outstanding successes when compared with the patient's previous experience wearing dentures.

10. The tissue-conditioning treatment is an adjunct of denture construction with high potential for promoting denture comfort. It is beneficial in the oral rehabilitation of edentulous patients who have denture sore mouths and are discouraged or physically or mentally sick. The procedure is a positive factor in doctor-patient relationship.

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RESTORING HEALTH AND COMFORT OF TISSUES UNDER DENTURES

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Restoration of tissue health for edentulous patients is ideally accomplished by removing the dentures from the mouth until the tissue recovers. However, the complex pattern of modern social and business life prevents this so often that other esthetically acceptable means must be considered.

TRANSITIONAL DENTURE SPLINTS

Transitional denture splints are used when the existing dentures are beyond rehabilitation. These treatment dentures are made from negative pressure impressions. The casts are relieved with 0.005 tinfoil before the denture bases are processed. The anterior teeth are arranged for esthetic appearance; the posterior occlusion is composed of contacting flat blocks of acrylic resin. Centric occlusion must be in harmony with centric relation at the proper vertical dimension of occlusion.

The internal surfaces of the completed splints are covered with a tissue treatment plastic material, and the splints are worn by the patient. The soft plastic is removed and replaced at intervals until normal tissue tone returns.

The splints are often used as immediate dentures. The absence of posterior teeth assures the patient that the restoration is a tissue treatment splint, and he happily anticipates new dentures.

A RELINING PROCEDURE

Dentures that need relining present problems which, without consideration before, during, and after the usual relining procedure, may multiply the patient's complaints. The method to be described was designed to re-establish centric relation and tissue-base compatibility in existing dentures with thermoplastic bases.

This indirect relining technique does not supplant the need for replacing the entire denture base with new material or for the construction of new dentures when gross tissue changes have occurred. The waiting time of the edentulous patient is reduced to a minimum, and the technique may be used for removable partial dentures, especially bilateral distal extension dentures.

A carefully made wax centric relation record placed bilaterally from each cuspid posteriorly to the second molars is utilized to equalize occlusal pressure.

Read before the Academy of Denture Prosthetics in San Juan, Puerto Rico.

The wax interocclusal record corrects disharmonies of centric occlusion by creating an equalized contact for which the tissue treatment plastic or impression material will compensate on the tissue side of the denture.

MAXILLARY IMPRESSION

The treatment plastic (if used previously) is removed from the maxillary denture, and all undercuts in the denture base are relieved. Holes are drilled through the denture base at the gingival ends of the teeth between the central incisors and distal to each cuspid with a No. 10 round bur. Two more holes are drilled at the location of the posterior palatine foramina. Then, the entire tissue surface of the denture is painted with rubber cement.

A thin mix of syringe rubber-base impression material is spread over the entire tissue surface and the borders of the denture. The denture is placed in the mouth in an upward and backward direction and seated firmly. The three escape holes in the labial flange prevent build-up of hydraulic pressure which might displace the denture anteriorly. The mandibular denture is positioned, and the patient closes the mouth into the wax centric relation record.

MANDIBULAR IMPRESSION

The maxillary denture with the completed rubber-base impression in it is placed in the mouth. The length of the lower denture borders is evaluated, and, if necessary, modeling compound or heavy-bodied rubber-base impression material is added to correct the extension of the flanges. When ridge conditions are unfavorable, four holes are drilled through the lingual flange of the denture in the region of the second molars and first bicuspids.

Rubber cement is painted over the impression surface of the denture, and a thin-bodied mix of rubber-base impression material is applied. The denture is seated, and the patient is instructed to close the teeth into the wax centric relation record. The tongue is raised to touch the lingual surfaces of the upper anterior teeth in order to border mold the lingual flanges.

REMOUNTING RECORDS

A face-bow record is made and laid aside. The Coble pin and platform are mounted on the dentures for purposes of equalizing pressure and locating the centric relation point on the occlusal platform. The modeling compound is carefully attached to the denture-base material (not to the rubber-base material) when the platform is positioned. The tracing pin on the upper denture is adjusted so there is no contact between the upper and lower teeth on hinge closure.

A needle point tracing is scribed on the occlusal platform. However, a sharp apex may not be developed because of the Bennett movement. The series of exercises suggested by Boos[1] is helpful for training patients to make the desired jaw movements for making the tracing.

I do not accept the apex of the needle point tracing as the centric relation point until it has been verified as the hinge axis centric position. The needle point

tracing is covered with a small square of thin blue articulating paper, and the patient is instructed to relax the mandible. Then, the hinge axis centric relation without strain is located as the patient tap, tap, taps into a spot. The dentures are removed, and the blue dot must be made consistently in the same spot, regardless of the location of the apex of the needle point tracing. To check this record, the tap, tap procedure is repeated using red nylon typewriter tape. The red dot must obliterate the blue spot.

Quite often, the centric relation dot is slightly anterior (on the lower platform) to the apex of the needle point tracing produced by horizontal jaw motions. This most retruded position is the starting point for developing the occlusion.

A clear plastic disk with a beveled hole in it the same size as the tracing pin is positioned over this centric relation point. The patient is asked to tap the teeth into the hole several times for practice. The upper and lower teeth are lightly lubricated. Then, thoroughly softened wax is adapted over the occlusal surfaces of the upper posterior teeth.

The patient is instructed to close into the wax in centric relation. Upon removal of the dentures, the central bearing (tracing) pin must be in the hole in the plastic disk. The dentures are disengaged from the chilled wax, and the buccal and lingual walls of the wax interocclusal record are carved away.

The central bearing point is shortened a fraction of a millimeter to compensate for rebound of soft tissues. Otherwise, the dentures would rock a little in the wax records because of pressure on the central bearing pin.

The wax interocclusal records are filled with zinc oxide–eugenol paste and placed on the lower denture; then centric relation closure is repeated. (The wax record serves as a carrier for the zinc oxide–eugenol paste.) The perfected interocclusal records are trimmed and carefully removed from the previously lubricated denture teeth and saved for remounting and grinding centric occlusion. Then, the Coble balancer is removed. Protrusive and lateral wax records are made and laid aside for relating the casts in the eccentric positions.

LABORATORY PROCEDURE

The impressions are boxed, and casts are poured in artificial stone to which a small amount of kaolin has been added to reduce the setting time. Each denture and cast is mounted *separately* on a stable plane line articulator or the Hooper duplicator. A stone matrix of the teeth is made with the instrument in a closed, fixed position. An extension of stone is built up from the posterior end of the matrix to contact the opposite stone base in a V-shaped wedge. This extension serves as a stop and produces condensation pressure on the activated resin to be used later.

The dentures are removed from the casts, the impression surfaces of the dentures are cleaned and scarified, and gross undercuts are removed. The casts are treated in the same manner as those for a new denture. A light coating of petroleum jelly or silicone compound is painted over the polished surfaces of the dentures and the teeth.

A mix of cold-curing acrylic resin is placed in the denture. (A proportion of about 1 part of monomer to 3 to 3½ parts of polymer is used.) The resin monomer is kept in the refrigerator to extend the setting time and permit better penetration in the polymer. The denture is fitted part way onto the cast and the teeth part way into their matrix, then the instrument is closed until all stops are flush. The holes made through the dentures during the impression procedure provide escape vents for the excess material. The closed instrument is held with elastic bands or C clamps.

The entire assembly is covered with tepid water in a pressure cooker, and air pressure of 35 to 50 pounds is introduced into it. The pressure is maintained for at least ½ hour. This assists the monomer to penetrate into the polymer and develops a material with great density.

The casts are removed from the articulator or duplicator. Before the dentures are removed, the casts are mounted on an adjustable articulator by means of the face-bow and centric relation records that were made previously. The lateral and protrusive records are used to adjust the condylar guidances on the articulator. The teeth are corrected to produce an equalized centric occlusal contact and to accommodate the eccentric movements, including slight anteroposterior freedom of intercuspation.

The dentures are removed from the casts, placed under vacuum for several minutes to volatilize any residual monomer, trimmed, and polished.

CONCLUSIONS

The relining procedure duplicates the occlusion that existed prior to treatment. The accurate jaw relation records and the face-bow transfer are used to harmonize centric occlusion with centric relation, which is so essential to stability of denture bases.

The remounting procedure is employed to correct pre-existing but unrecognized malocclusions.

The technique is designed not solely for speed; however, by eliminating flasking and heat curing, it is relatively fast.

Relining of dentures is done so frequently that it is done haphazardly because speed is important to the patient. Accuracy of the relining procedure should be of great concern to the dentist, and the technique should be held in high regard by the public.

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THE RELATION OF DEGLUTITION TO THE MASTICATORY MECHANISM

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THE PHARYNX is one of the most complex organs of the human body. Its performance in deglutition, respiration, and phonation is one of the most delicate neurophysiologic phenomena. This article describes the salient points of anatomy and physiology of the pharynx and their relation to the masticatory mechanism and function of complete dentures and obturators.

ANATOMIC CONSIDERATIONS

The pharynx is a tubular passage approximately 12.5 cm. long which commences at the base of the cranium and extends vertically to the esophagus. Anteriorly, in its uppermost part, the pharynx communicates with the nasal cavity and is called the nasopharynx. This part has a strictly respiratory function. Below, the pharynx communicates with the oral cavity and is called the oropharynx. This serves as a passage for both food and air. The lowest part of the pharynx is the the laryngopharynx, which communicates with the opening of the larynx and also serves both alimentary and respiratory purposes.

The pharyngeal tube is widest anteroposteriorly as well as laterally in the area of the nasopharynx and becomes constricted as it descends to the oral and laryngeal openings, respectively. The lateral or transverse diameter is broader than the anteroposterior diameter. Anteriorly, the pharyngeal tube is incomplete and is attached successively to the base of the cranium, the medial pterygoid plate, the pterygomandibular raphe, the posterior part of the mylohyoid ridge, the tongue, the stylohyoid ligament, the hyoid bone, and the thyroid cartilage.

Posteriorly, the pharynx is connected to the cervical vertebral column by a layer of loose areolar tissue. The tissue connects the thin tunica fibrosa in front to the prevertebral fascia behind.

Laterally, the pharynx is attached to the styloid processes and their muscles.

The pharynx is made up of three layers: mucous, fibrous, and muscular. The pharyngeal aponeurosis, or fibrous layer, is situated between the mucous and the muscular layers. In dissecting the posterior wall of the pharynx from the ventral surface to the cervical vertebral column, the following structures are observed: the mucous membrane, the pharyngeal aponeurosis, the muscular layer, the thin tunica fibrosa, the layer of areolar tissue, and the prevertebral fascia which covers the longus colli and longus capitis muscles.

Read before the Greater New York Academy of Prosthodontics, New York, N. Y.

The mucosa is attached to the base of the cranium, where it is of thick consistency and dark in color. As the mucosa descends to the auditory tubes and the choanae, it becomes thinner; still lower it becomes more pale and is formed into longitudinal folds.[1]

The interval between the upper free border of the superior constrictor muscle and the base of the skull is known as the sinus of Morgagni. The sinus is closed by the pharyngeal aponeurosis which is well marked in front of the pharyngeal spine of the basilar process of the occipital bone. The aponeurosis extends from the occipital bone to the undersurface of the apex and adjacent petrous portion of the temporal bone. It descends to the auditory tubes and to the medial plates of the pterygoid process. From there, the aponeurosis runs along the pterygomandibular raphe to the posterior segment of the mylohyoid ridge of the mandible and passes then along the side of the tongue to the stylohyoid ligament, the hyoid bone, and the thyroid cartilage. The farther the aponeurosis is from its origin, the thinner it becomes, and gradually it becomes lost. The aponeurosis is reinforced posteriorly by a strong fibrous band which is attached above to the pharyngeal spine of the occipital bone and descends forming a median raphe which gives attachment to the pharyngeal constrictor muscle. Externally to the pharyngeal aponeurosis is situated the thick muscular layer of various cross-striated muscles arranged so they can respond instantaneously to any forthcoming demands.

The pharynx is the organ in which mastication, deglutition, respiration, and phonation are not only correlated but harmoniously integrated with extreme rapidity. The muscles capable of achieving this remarkable work are chiefly sphincter-like constrictors in function. They include the glossopalatine muscles which constrict the faucial isthmus, the pharyngopalatinus muscles which constrict the pharyngeal isthmus, and the superior, middle, and inferior pharyngeal constrictors. The stylopharyngeus, pharyngopalatinus, and salpingopharyngeus muscles represent a ring of incomplete vertical layers of muscles enclosing the circularly arranged constrictors of the pharynx.

In instances of advanced specialization of the pharynx, the longitudinal and circularly positioned muscles are so interwoven and intertwined that it is difficult to determine whether the circular muscles enclose the longitudinal or the longitudinal enclose the circular ones. The extreme elasticity and flexibility and the rich texture in the interrelatedness of all the structures composing the pharynx constitute the secret of its extraordinary and exceptional speed of mobility.

MECHANISM OF DEGLUTITION

The physiology of deglutition may be divided into four stages in accordance with the course the bolus pursues from the mouth into the esophagus: (1) mastication, trituration, and insalivation of the bolus within the oral cavity, (2) propulsion of the bolus from the oral cavity proper into the pharynx, (3) conveyance of the bolus through the pharynx, and (4) propulsion of the bolus through the laryngopharyngeal sphincter into the esophagus.

These four stages are closely interdependent. Thus, the more thorough the mastication, trituration, and insalivation of the bolus within the oral cavity, the

easier is its propulsion into the pharynx. Similarly, the less the bolus irritates and tickles the pharyngeal mucosa, the quicker and smoother are its conveyance through the pharynx into the laryngopharynx. And finally, the more uneventful the passage of the bolus up to the laryngopharynx, the easier is its penetration through the laryngopharyngeal sphincter.

There are many theories and conflicting statements concerning the elaborate functions of the musculature of the pharynx. One contributing factor to these conflicting views may be that the studies of the anatomy and physiology of the maxillofacial structures are not correlated with those of the head and neck.

A second reason may be the complicated convergence of the suprahyoid and infrahyoid muscles to the hyoid bone and the simultaneous participation in function of all the muscles of deglutition with those involved in mastication. All this is further complicated because certain other muscles (the sternomastoid, trapezius, longus colli, and longus capitis) which are concerned with various head postures are frequently invoked to assist in the deglutitive process.

Further difficulty derives from the inability to reach some of the muscle groups or individual muscles for study purposes by either cinefluography or electromyography. However, most of the theories extant on the subject of deglutition are based on studies with the aid of fluoroscopy, cinefluoroscopy, and electromyography.

THEORIES AND HYPOTHESES

About 1880, the theory was proposed that fluids and semifluids are propelled directly into the stomach by the contraction of the tongue and mylohyoid muscles effecting a syringelike action to pressure the liquids downward. The muscles of the pharynx proper came into play only for propulsion of solid food substances.

Another concept of the mechanism of deglutition was advanced as the result of the use of fluoroscopy. A radiolucent area in the laryngopharyngeal cavity was observed just prior to the propulsion of the bolus into the pharynx. The radiolucent area disappeared immediately to provide space for the bolus. This concept gave rise to the theory of an instant negative pressure within the laryngopharyngeal cavity that pulled the bolus in by suction.

The concept that the process of deglutition is performed successively by contraction of the oral, pharyngeal, and esophageal muscles has been confirmed by the roentgenographic studies of Bosma.[2] He also announced a new theory based on his roentgenographic studies which he calls "motion in anticipation of the approaching bolus."[3] Bosma was impressed by a particular position or posture assumed by the upper part of the pharynx and the consecutive elevation of the larynx and laryngopharyngeal area an instant prior to penetration by the bolus.

All theorists agree that the pharynx is endowed with extreme rapidity of motion and, therefore, that all structures involved in deglutition must be exceedingly flexible and elastic. Correspondingly, these structures, while favoring the mobility of the pharynx, make it more vulnerable to impairment by various pathologic conditions such as peritonsilar, parapharyngeal, and postpharyngeal absecesses as well as by abscess in the thyroglossal duct of the tongue.

Structures of the anterior boundary of the pharynx, that is, the tongue, hyoid bone, and larynx, may be displaced posteriorly to the vertebral column. This condition is characteristic of individuals with weakness of the cervical muscles, as in instances of poliomyelitis. Similar tongue displacement may occur in individuals who have had an excessively insufficient vertical dimension of occlusion for a long time and in persons who wear complete dentures or even a single upper denture deficient in retention. All these deficiencies lead to difficulty in deglutition.

TRAUMATIC OCCLUSION AND IMPAIRMENT IN DEGLUTITION

Lack of occlusal harmony between the upper and lower occlusal surfaces of the teeth in centric occlusion is a frequent cause of a disturbance in deglutition. Every time the bolus of food is ready to be propelled into the pharynx, deflective occlusal contacts of the opposing masticatory surfaces upset the delicate reflex interaction between the mechanisms of mastication and deglutition. The patients register vague complaints of severe discomfort, a sensation of almost choking while swallowing. These complaints are frequently disregarded and suspected of being emotional in nature. The patient hardly has any other way to describe the symptoms except to characterize them as a sensation of choking.

The dentist must command a good working knowledge of anatomy and physiology before he is able to proceed with a scientific clinical study of this symptomatology. These clinical symptoms must be analyzed on an adequate number of patients, correlated, and, if possible, integrated with well-established data on anatomy and physiology. The synthesis of all the factors participating in the interaction and interplay of the masticatory mechanism with the mechanisms of deglutition and respiration provides a clue to an etiologic diagnosis of the "sensation of choking."

I conducted a study of the time interval between mastication and deglutition and found the interval to be characterized by a static contact between the mandibular and maxillary teeth associated with centric relation. This can be utilized as one of the tests in establishing and checking the correctness of the centric relation record.

Preceding this centric occlusal contact of the teeth in the deglutitive process, the anterior third of the tongue presses against the lingual surface of the upper anterior teeth and the anterior third of the palatal vault. Then, the middle part of the dorsum of the tongue presses against the palatal vault for the propulsion of the bolus into the pharynx.

INADEQUATE DENTURE RETENTION AND THE SWALLOWING MECHANISM

The swallowing mechanism deteriorates when the upper denture is lacking in retention and stability, particularly from a faulty posterior palatal seal. The pressure of the tongue against the lingual inclined planes of the upper anterior teeth loosens the upper denture by leverage, and it drops posteriorly. The space between the posterior border of the denture and the dorsum of the tongue becomes markedly reduced, and this renders the propulsion of the bolus through the faucial isthmus into the pharynx rather embarrassing for the patient.

Some of these patients complain that their difficulty in swallowing is caused by the lower denture "swimming around." They do not realize that while the tongue is unconsciously raised to prevent the upper denture from dropping, the mylohyoid muscles are displacing the lower denture upward. The real culprit is the upper denture. The patient is suffering from a choking sensation that does not reside in the pharynx but in the ill-fitting, loose upper denture. This is not globus hystericus but a typical physical condition misdiagnosed at times as of emotional origin.

SOFT PALATE AND POSTERIOR WALL OF PHARYNX VIEWED CINEFLUOROGRAPHICALLY

For a long time, it was believed that when the bolus penetrated the pharynx, the soft palate was pulled upward and backward to effect contact with the ventral surface of the posterior wall of the pharynx at Passavant's cushion to prevent penetration of liquids into the nasopharynx.[4] I have made many cinefluorographic exposures of deglutition which show that the contact of the uvula with the posterior pharyngeal wall is effected at a much higher level than has been recognized. Cinefluorographic studies indicate it to be so.

This new finding is of great practical significance in cleft palate rehabilitation whether surgical or prosthetic procedures are employed. The contact at the higher level is by far more effective in preventing the liquids and solid substances from penetrating into the nasopharynx. The raised position of the tongue and the contraction of the constrictors of the faucial isthmus (glossopalatine muscles) and the constrictors of the pharyngeal isthmus (pharyngopalatinus muscles) prevent the bolus from returning into the oral cavity.

Simultaneously with the teeth effecting contact in deglutition, the stylopharyngeus muscles contract to dilate the pharynx because their origins at the styloid processes are farther apart than their insertions on the sides of the pharynx. Thus, the contraction of these muscles draws the pharynx upward and laterally. The diameter of the pharyngeal tubular passage also increases in breadth in an anteroposterior direction by elevation and forward protraction of the tongue, larynx, and hyoid bone.

The pharyngopalatine muscle which inserts into the posterior and lateral walls of the pharynx and the areolar tissue that fills the retropharyngeal space contribute to effective and rapid mobility of the pharynx. The elevation and forward protraction of these structures also place the larynx under the shelter of the base of the tongue; in this way, food is prevented from entering the larynx.

MANDIBULAR OVERCLOSURE AND POSITION OF HYOID BONE

I conducted a series of experiments upon myself utilizing cineroentgenography (image intensification). These experiments were conducted with solid foods coated with barium and also while drinking and gargling liquid barium. Careful study and observation of the film made of these cineroentgenographic exposures tended to indicate that the hyoid bone moved forward perceptibly more when the jaws were brought into occlusion for swallowing than it had when cinefluorographic

tests were made on myself 6 years previously. The hyoid bone descends slightly downward and backward when the mandible assumes a position of rest.

The difference in the position of the hyoid bone in these experiments might be explained by the closure of the vertical dimension of occlusion that took place during the elapsed period of 6 years. This in turn suggests the hypothesis that with a marked decrease in the vertical dimension of occlusion, the tongue, hyoid bone, and larynx tend to be displaced (gradual and small as the displacement may be) in the direction of a closer approximation with the cervical vertebral column. If there is inadequate time for readaptation to new environmental conditions, such displacement will impair somewhat the physiologic state of deglutition and respiration.

CONCLUSION

The interrelationship and intimate interdependence between mastication, deglutition, respiration, and phonation are, from a neurophysiologic standpoint, overwhelmingly intricate and extremely fascinating. The instantaneous interaction and smooth performance of these vital functions require a complex integration of the cranial somatic innervation in coordination with the autonomic nervous system. The heightened awareness that the oral cavity with its adjacent and associated structures (the area of the dentist) plays such a vital and distinctive role in human physiology is certainly most gratifying and encouraging. Even our most mechanically minded colleagues are beginning to realize that *biologic values are basic in dental practice and dental research.* Total acceptance and complete recognition that biologic values form the very foundation of denture prosthesis will greatly reduce the number of elusive factors that lead to failures in this specialty of dentistry.

A serious attempt to correlate and integrate structure and function in the oronasopharyngolaryngeal structures still must wait upon a great deal more study and research. Not only are senility and disease etiologically multifactorial, but all physiologic processes in living organisms in various stages of their development are the resultants of a constellation of many factors. Some of these factors are the genetic characteristics of the cells, tissues, and structures involved, their ability to re-establish and maintain homeostasis, the influence of the endocrine systems, nutrition, metabolism, and the influence of various mechanical phenomena.

Clinical observations and cinefluorographic investigations indicate that none of the extant theories on the conveyance of the bolus through the pharynx can be accepted as definitive. The answer will probably come from a synthesis of concepts of various investigators after study of this subject under different spectra and from new and original approaches.

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CLINICAL AND ELECTROMYOGRAPHIC STUDY OF MANDIBULAR REST POSITION

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THE ESTABLISHMENT of a proper vertical dimension of occlusion is one of the greatest problems in complete denture construction. Few valid rules and principles are available. Swenson[1] described the situation in this manner: "This is an extremely vexing problem. It plays such a great part in the success of a denture that it is unfortunate that it is usually a matter of judgment in the hands of the dentist during the construction."

PHYSIOLOGIC REST POSITION

No single aid is more helpful in establishing the vertical dimension of occlusion than the relationship that exists between that dimension and the physiologic rest position of the mandible. Thompson[2] made the entire dental profession aware of the constancy of the rest position. He pointed out that rest position may well serve as a base point for the determination of the vertical dimension of occlusion in complete denture construction.

POINT METHOD OF ESTABLISHING VERTICAL DIMENSION OF OCCLUSION

Perhaps the most widely used application of Thompson's principles in complete denture construction is the method described by Pleasure.[3] Adhesive tape triangles are placed on the nose and chin. With the patient in the correct postural position, mandibular movements are induced by swallowing, lip moistening, and letter pronunciation until a stable rest position is established. The distance between the triangles is measured with a gauge. This procedure is repeated a number of times, and the dentist finally selects the measurement with the greatest regularity as an indication of the rest position. The vertical dimension of occlusion is determined by

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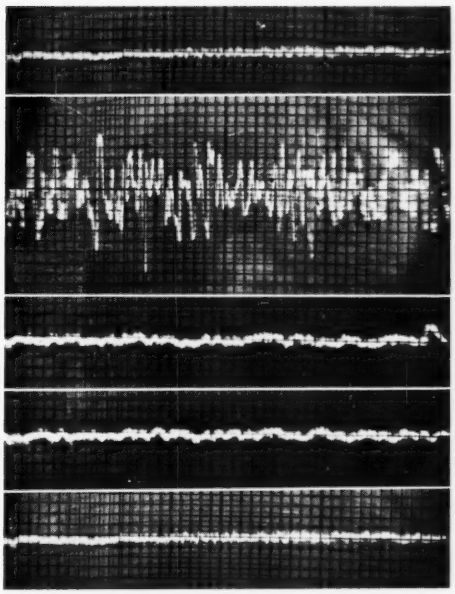

Fig. 1.—An electromyogram indicating rest position is made from a surface electrode attached to the skin over the left masseter muscle. The subject is standing.

Fig. 2.—Increased electrical activity occurs when the mandible is opened beyond rest position.

Fig. 3.—An electromyogram of rest position is made from a needle electrode inserted into the left masseter muscle. The subject is seated with the backrest in position.

Fig. 4.—An electromyogram made under similar conditions as in Fig. 3, but without the backrest.

Fig. 5.—An electromyogram made under similar conditions as Fig. 3, with the subject standing.

reducing this figure a suitable amount to provide for the interocclusal distance. The occlusion rims are adjusted to maintain this measurement.

The accuracy of the point and gauge method is dependent on the correct determination of the physiologic rest position of the mandible, which is the position at which the elevator and depressor muscles are in a state of equilibrium. The electromyograph is an instrument that measures the relative electrical activity in muscles. Shpuntoff and Shpuntoff[4] showed that the same mandibular rest position could be duplicated at succeeding intervals with the electromyograph. Therefore, the electromyograph was used as a check on the accuracy of the point method.

METHODS

Twenty-six subjects were studied. Six were dentulous and 20 were edentulous. Both men and women were included in the study, and the average age of the group was 56.5 years.

A single channel electromyograph unit* was adjusted to a calibration of 100 μV per inch. Lightweight surface electrodes 9 mm. in diameter were used. The

*Meditron type 201A.

TABLE I. THE DIFFERENCE BETWEEN THE MEASUREMENT OF THE PHYSIOLOGIC REST POSITION DIMENSION AS DETERMINED BY THE POINT AND GAUGE METHOD AND THE TRUE PHYSIOLOGIC REST POSITION DIMENSION AS DETERMINED ELECTROMYOGRAPHICALLY USING DISK ELECTRODES

SUBJECT	SITTING		STANDING	
	DECREASE (MM.)	INCREASE (MM.)	DECREASE (MM.)	INCREASE (MM.)
A	0.3			0.4
B	0.0	0.0	1.0	
C	0.0	0.0	0.0	0.0
D	2.4			1.6
E	0.2		0.0	0.0
F	0.0	0.0	1.0	
G	0.0	0.0	0.0	0.0
H		4.5		2.2
I	0.0	0.0	1.0	
J	0.7			1.3
K	0.0	0.0	0.2	
L	1.0		2.0	
M	1.3			3.5
N	0.0	0.0	0.0	0.0
O		2.0		2.0
P	0.0	0.0		1.0
Q		1.0		1.0
R		2.0		1.0
S		1.0		1.0
T		0.5	0.0	0.0
U		2.0		1.0
V	1.0		1.0	
W		1.0		2.0
X		1.0		1.0
Y		1.0		1.0
Z	2.0		1.5	
Totals	8.9	16.0	7.7	20.0
Averages	0.56	0.89	0.64	1.05

left masseter muscle was carefully palpated, and the active electrode was placed opposite the center of the belly of the muscle. The reference electrode was placed approximately 1 cm. below the active electrode. The ground plate was attached to the lobe of the ear using an earring type of connection. Standard electrode paste was used, and all determinations involving the electromyograph were made in a Faraday cage to screen out electrical disturbances.

The nose-chin distance was measured first using the point method. The subject was in the sitting position but free of the headrest and backrest. Then the electrodes were attached, and, as the subject watched the oscilloscope and listened to the sound, the effects of jaw movements on the instruments were demonstrated. The subject was instructed to locate the jaw position that resulted in a minimum of activity in the electromyograph.

The mandible was considered to be in the rest position when the electromyograph indicated a minimum of neuromuscular activity within the muscle. This

position resulted in a minimum of movement in the electron beam of the cathode ray oscilloscope and a minimum of sound from the audio circuit (Figs. 1 and 2). The same worker again measured the nose-chin distance. All measurements were repeated with the subject standing.

As a check on the effectiveness of the surface electrodes, needle electrodes were used, and the same measurements were repeated on 3 of the subjects on whom surface electrodes had previously been used (Figs. 3 to 5). A coaxial needle electrode was inserted into the belly of the masseter muscle. The ground electrode was attached to the ear lobe in the same manner used for the surface electrodes.

RESULTS

In the sitting position, 8 subjects had the same vertical dimension of rest position by the point method as they did by the electromyographic method. Eight other subjects had a greater closure, averaging 0.56 mm., by the point method than they did electromyographically. The remaining 10 subjects had a greater opening, averaging 0.89 mm., by the point method than they did when the rest position was located by the electromyograph.

In the standing position, the two methods produced identical results for 5 subjects. The point method resulted in overclosure with 7 subjects, for an average of 0.64 mm., and in an excessive opening with 14 subjects, for an average of 1.17 mm., when compared with the electronic method (Table I).

The results obtained with needle electrodes basically substantiated the measurements obtained with the surface electrodes (Table II).

DISCUSSION

Although at first inspection the data might appear to favor the sitting position, the difference is so slight that it is not considered significant. The data indicate that the dentist errs more often by establishing a greater vertical dimension of rest position rather than a lesser dimension when using the point method. These findings do not support the common clinical observation that after establishing the vertical dimension of occlusion with the point method, clinical judgment

TABLE II. THE DIFFERENCE BETWEEN THE MEASUREMENT OF THE PHYSIOLOGIC REST POSITION DIMENSION AS DETERMINED USING THE POINT AND GAUGE METHOD AND THE TRUE PHYSIOLOGIC REST POSITION DIMENSION AS DETERMINED ELECTROMYOGRAPHICALLY USING NEEDLE ELECTRODES

SUBJECT	SITTING		STANDING	
	DECREASE (MM.)	INCREASE (MM.)	DECREASE (MM.)	INCREASE (MM.)
C	0.0	0.0	0.0	0.0
L	1.0		1.0	
Z	3.1		0.7	

and experience frequently dictate additional opening. This might be due to efforts to achieve the maximum esthetic result. The inadvisability of constructing dentures to a vertical dimension of occlusion that exceeds the physiologic limits is obvious.

CONCLUSIONS

The electromyographic method of establishing the vertical dimensions of rest position shows a true physiologic rest position of the mandible. The results confirm the accuracy of the point and gauge method for establishing the vertical dimension of occlusion. Because of elaborate equipment and time, the electromyographic method is not practical in the average dental office; however, the point method is satisfactory in obtaining true measurements. Both standing and sitting positions without the headrest and backrest appear to be equally advantageous when locating the physiologic rest position of the mandible.

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CEPHALOMETRIC ANALYSIS OF THE VERTICAL DIMENSION OF OCCLUSION

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THE VERTICAL DIMENSION OF OCCLUSION is one of the important reference points in successful complete denture construction. Numerous techniques are used to determine this relation, but no reliable method is available to evaluate their accuracy.

Orthodontists use cephalometric roentgenography, a scientific means of measuring bone growth by comparative measurements of serial roentgenograms, to trace treatment progress and for study purposes.[1] A cephalostat was selected as a measuring aid to study three common methods of recording the vertical dimension of occlusion.

POSITIONING THE CEPHALOSTAT

The cephalostat was installed in a fixed position, and the bracket that positions the roentgen tube was mounted at a 60 inch target to film distance. The cephalostat was focused so that the central rays would pass through the exact center of the ear pieces that hold the head in position. Pre-extraction cephalometric roentgenograms recording the vertical dimension of occlusion were made.

ROENTGENOGRAPHIC TRACINGS

Tracings of pertinent landmarks, lines, and measurement areas were made from each roentgenogram. Superimposition of successive tracings was facilitated by the selection of identical reference points, bone landmarks and drawn lines and planes (Fig. 1): (1) the cranial base line, a line drawn from the center of the sella turcica to the nasion *(SN),* (2) the Bolton plane, a line drawn from the Bolton point to the nasion, (3) a line drawn from the sella turcica perpendicular to the Bolton plane, and (4) the anterior nasal spine. The lines that were used to locate the point of measurement were (1) the facial line, a line projected from the nasion through the anterior border of the symphysis, and (2) the mandibular line, a line paralleling the lower border of the mandible and projected to cross the facial line. This cross point is identified as *0.*

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The distance in millimeters along the facial line from the nasion *(N)* to the cross point is the measurement of the vertical dimension of occlusion. Any vertical deviation can easily be determined by comparing this measurement with that of any previous studies made on the same patient.

TECHNIQUES FOR ESTABLISHING THE VERTICAL DIMENSION OF OCCLUSION

Three widely used techniques were selected to determine the vertical dimension of occlusion. The results from these techniques were compared with records of the pre-extraction vertical dimension of occlusion.[2]

Phonetics and Esthetics.—The upper occlusion rim was contoured to give adequate lip support and indicate correct tooth length. The lower occlusion rim was developed to provide an approximately 3 mm. interocclusal distance. Centric relation was recorded, and the casts were mounted on a Hanau model H articulator. Phonetics was considered during the try-in.[3]

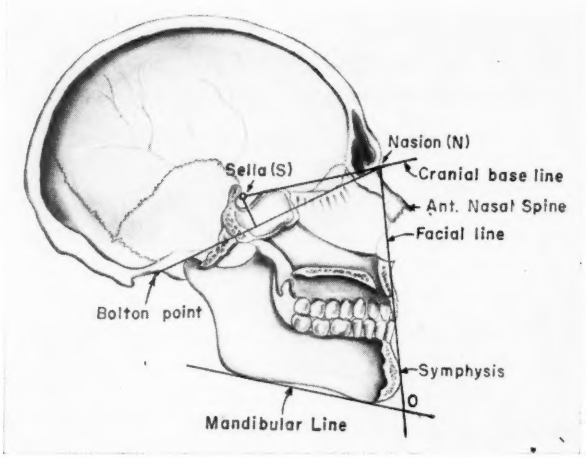

Fig. 1.—A schematic drawing shows the orientation landmarks and the location of projection lines for the measurement of the vertical dimension of occlusion.

Tactile Muscle Sense.—The same upper occlusion rim and lower acrylic resin baseplate were used. A softened wax rim was attached to the lower baseplate. The rims were placed on the articulator, which was slowly closed until the incisal guide pin was 8 mm. above the incisal guide table. This provided a controlled amount of wax for the patient to reduce. Then, the wax on the lower baseplate was uniformly softened in warm water and inserted into the mouth with the upper occlusion rim. The patient was instructed to close the teeth into the wax until he felt that the jaw separation was similar to his pre-extraction dimension. Then, centric relation was recorded.[4]

Physiologic Deglutition.—The same procedure as in the tactile sense technique was followed, except that the patient was asked to touch the softened wax on the lower baseplate lightly against the upper occlusion rim and then to suck and

swallow. This procedure was repeated three times. Centric relation was usually recorded along with the vertical dimension of occlusion.[5]

INVESTIGATIONS AND SUBJECTS

Two investigations, A and B, carried out independently of each other, involved use of all three techniques on each subject. Accordingly, one pre-extraction record of the vertical dimension of occlusion and six subsequent records of the vertical dimension of occlusion were made for each of 26 subjects selected to participate in this study. Thus, a total of 156 records, not including the pre-extraction records, were made.

Investigation A, which was done by a single dentist, consisted of use of all three techniques on all subjects. In investigation B, three other dentists worked together for added fluidity and as a cross check. At no time did any dentist see any of the roentgenograms until his series was completed.

No attempt was made to select subjects according to age group, cooperativeness, or whether or not they were potentially good denture patients. The only criteria considered were (1) a need for the extraction of all remaining natural teeth and (2) sufficient posterior tooth contacts in harmony with centric relation to maintain a relatively normal vertical dimension of occlusion. The study was started 3 months after the last teeth were extracted.

RESULTS

Reducing the interocclusal distance more than 1 mm. from normal is usually considered undesirable. Since reducing the vertical dimension of occlusion increases the interocclusal distance, a 1 mm. reduction of the vertical dimension was considered acceptable. The spread of 2 mm. from -1 to $+1$ mm. seemed to be within a normal range, and it was accepted as correct for purposes of comparison. The variations between the established vertical dimension of occlusion and the pre-extraction relation are seen in Table I.

There was a great variation between the number of registrations of the vertical dimension accepted as correct (27.5 per cent) and those found to be decreased (58.7 per cent) (Table II). The number of registrations that were increased 2 mm. or more (13.4 per cent) was similar to those decreased 5 mm. or more (14.7 per cent). Technique 3 seemed to be slightly more desirable in the number of correct registrations recorded (32+ per cent), with a lesser number of instances of decreased vertical dimension of occlusion (51 per cent). However, technique 3 also resulted in the greatest number of increased vertical dimensions of occlusion recorded (15 per cent), as compared to techniques 1 and 2 and to the over-all average (13.4 per cent). The twenty-three closed registrations included in the 5 mm. or more category fell mainly into two major groups, one a group of 9 subjects measuring 5 mm. and the other a group of 8 measuring 8 mm. The remaining registrations were from 6 mm. to 13 mm.

One wonders how the vertical dimension of occlusion could be decreased as much as 13 mm. (Table I, patient 21). However, with this patient, in investigation

A, there were two registrations at −7 mm. and one at −8 mm; in B, two at −11 mm. and one at −13 mm. Interestingly enough, of the twenty-one registrations that were increased 2 mm. or more, none were increased 4 mm. or more.

SUMMARY

Three commonly used techniques to establish the vertical dimension of occlusion were tested. Cephalometric roentgenography was used to record and evaluate their comparative accuracy.

A number of dentists participated in the clinical phase of the investigation to obtain as unbiased a pattern as possible and to be a check upon each other.

CONCLUSIONS

1. Cephalometric roentgenography can be used to measure and evaluate the accuracy of different techniques used to establish the vertical dimension of occlusion.

2. The most common error found by recording the vertical dimension of occlusion by all methods tested was excessive overclosure (58.7 per cent).

3. A variation in the results of the three techniques was anticipated, but the

TABLE I. DIFFERENCES IN MILLIMETERS BETWEEN PRE-EXTRACTION AND POSTEXTRACTION RECORDS OF THE VERTICAL DIMENSION OF OCCLUSION

PATIENT	TECHNIQUE 1		TECHNIQUE 2		TECHNIQUE 3	
	A	B	A	B	A	B
1	−2	−1	−1	−4	−1	−4
2	−1	+2	−2	+2	0	+2
3	+2	+1	+1	0	+2	+1
4	−1	−3	+2	0	+3	−1
5	−4	−3	−6	−1	−2	0
6	0	+2	−1	+2	−1	0
7	−3	−5	−3	−5	0	−5
8	0	+2	0	+2	+1	+3
9	−5	−5	−4	−5	−4	−2
10	−3	−3	−3	−3	−3	−3
11	−3	−2	−4	−1	−3	−2
12	−4	−3	−4	−3	−1	−3
13	−8	−8	−8	−5	−8	−3
14	−2	−2	−2	0	−2	0
15	−2	0	−2	−2	+2	+1
16	+1	+1	+3	−3	+3	−4
17	0	0	−5	−3	0	−3
18	−4	0	−1	−2	−4	−2
19	−3	−8	−5	−8	−4	−8
20	−2	−2	−2	−4	−2	−2
21	−7	−11	−8	−11	−7	−13
22	+2	−2	+1	−2	0	0
23	0	−2	0	−2	0	−2
24	−2	−2	−4	−3	−1	−2
25	+2	+2	+2	+1	+3	+3
26	−2	−3	−2	−3	−1	−4

TABLE II. THE CONSOLIDATED RESULTS AND PERCENTAGES

VERTICAL DIMENSION OF OCCLUSION	TECHNIQUES AND INVESTIGATIONS												TOTALS	
	1				2				3					
	A	B	A + B	%	A	B	A + B	%	A	B	A + B	%	NO.	%
Increased 2 mm. and over	3	4	7	13+	3	3	6	11+	5	3	8	15	21	13.4
Correct −1 to +1 mm.	7	6	13	24+	7	6	13	24+	11	6	17	32+	43	27.5
Decreased 2, 3, and 4 mm.	13	11	24	46	11	12	23	44	8	14	22	42	69	44.0
5 mm. and over	3	5	8	15+	5	5	10	19	2	3	5	9	23	14.7

difference between dentists using the same technique on the same patient was of little clinical significance.

4. With a few exceptions, if in investigation A the vertical dimension of occlusion was increased or decreased in the recordings, B was parallel in these recordings to a greater or lesser degree.

5. There was insufficient difference between techniques tested to set one aside as the outstanding technique.

6. The techniques studied appear to seriously require additional research and refinement to improve accuracy.

Dr. John E. West, Staff Dentist, Veterans Administration Hospital, Mountain Home, Tenn., gave valuable assistance in the early phases of this study. Acknowledgment also is given to Mr. Herbert C. Schonert for the art work and to Mr. Alex Gravesen, Chief, Medical Illustration Service, Veterans Administration Medical Teaching Hospital, Memphis, Tenn.

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POSTERIOR BORDER MOVEMENTS OF THE HUMAN MANDIBLE

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MANY AUTHORS have quoted Posselt's investigation of the mobility of the human mandible.[1-3] Posselt made tracings of the posterior border movements on 3 conscious subjects. After placing these subjects under general anesthesia plus curare, he again traced the border movements. He found no change in the position of these movements and concluded that the ligaments were responsible for limiting posterior border movements of the condyles.

The purpose of this investigation was to determine whether ligaments or muscles are responsible for limiting the posterior border movements of the condyles.

MATERIALS AND METHODS

The 12 subjects tested were both male and female, Negro and white, with ages ranging from 17 to 49 years. All subjects had at least ten teeth in each dental arch, to ensure stability of the clutches. "Subjects were randomly selected without prior attention to inherent clinical variables."[4]

An interocclusal wax centric occlusion record was made with the subject in the supine position. Impressions of the upper and lower teeth were made, and stone casts were poured. The casts were placed on a surveyor, and the teeth and tissue undercuts were eliminated with wax.

Stop pins (Fig. 2) 4 mm. in diameter were placed between the articulator condyle and anterior condylar stop. The casts were mounted on the articulator in centric occlusion. Since the articulator condyles are attached to the upper arm of the articulator (Figs. 1 and 2), the stop pins provided the equivalent of a potential space of 4 mm. behind the condyles.

The stop pins were not used for subject 1. Casts of subjects 1, 2, and 3 were mounted with a hinge-bow on a modified Hanau S-M-X articulator (Fig. 1). Casts of subjects 4 through 12 were mounted on a modified Italian Brevetto Galette articulator (Fig. 2).

The vertical dimension of occlusion of the casts was increased on the articulator to free the cusps in lateral movements. The amount of increase was never more than

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2 mm. except for subjects 7, 8, 10, 11, and 12. The vertical relation of occlusion for these subjects was increased beyond 2 mm. because of locked occlusion.

Tinfoil was adapted over both the teeth and the wax of the casts. An acrylic resin clutch was cured over the teeth of the casts. A modified Hanau needle point tracer was attached to the clutches with acrylic resin. The stylus and tracing plate and the central bearing pin and plate were parallel to the plane of occlusion and to each other. The clutches were made as thin as possible over the incisal and occlusal surfaces of the teeth. The cusps of some of the teeth protruded through the clutches so that the vertical opening would be less than 2 mm. (Fig. 3).

Lateral movements were made on the articulator and all interferences between the clutches were removed. The stop pins (Fig. 2) were removed, which allowed the upper arm of the articulator to move forward. This is equivalent to moving the lower arm posteriorly. All interferences between the clutches were again removed. The purpose of the stop pins was to allow for removal of interferences between the clutches while the mandible was in a position posterior to centric occlusion.

The stop pins were placed back in the articulator, and the tracing table was covered with carbon black. A needle point tracing was made on the articulator with the casts in centric occlusion. This tracing was used later to verify the original relationships.

Three photographs were made of the tracings from each patient. The first photograph was of the first centric occlusion tracing, the second was of the tracings made by the conscious patient, and the third was of the tracings made while the patient was under the influence of anesthesia and curare (Fig. 3).

PROCEDURE

Needle point tracings were made with the patients awake. The next day these tracings were repeated after the patients had been premedicated with meperidine

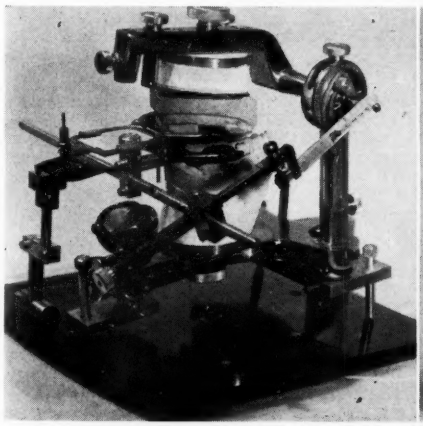


Fig. 1

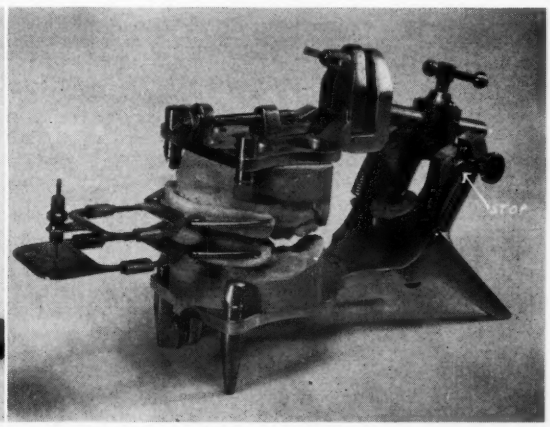


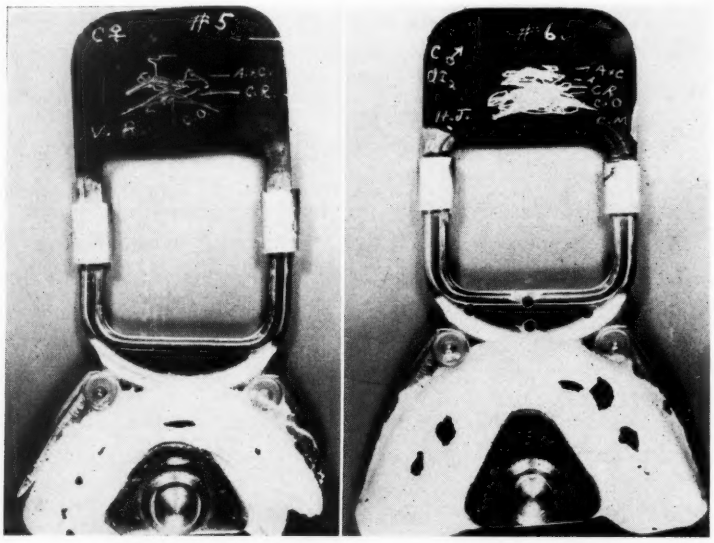
Fig. 2

Fig. 1.—The casts of 3 subjects were mounted on a modified Hanau S-M-X articulator. Note the mounting jig and modified needle point tracer.

Fig. 2.—The casts of 9 subjects were mounted on a modified Italian Brevetto Galette articulator. Note the anterior condylar stops.

and atropine. The tracings were repeated again with the patient under general anesthesia and with a nasotracheal tube in place. Anesthesia was induced with thiopental sodium, and maximal muscle relaxation was obtained with *d* tube curarine or succinylcholine chloride.

Needle point tracings were made on the first 6 subjects in both the sitting and supine positions. On subject 8, needle point tracings were made only in the first plane of anesthesia. On subject 6, tracings were made during the first three planes of the third stage, curare was administered during the third plane, and then a final needle point tracing was made. Tracings were made from subject 11 while he was under the influence of nitrous oxide and curare, additional thiopental sodium was administered, and another tracing was made. Curare was administered to subjects 2 and 5 in the first plane, and as the anesthesia became more profound,



A. *B.*

Fig. 3.—The tracings from subjects 5 *(A)* and 6 *(B)*: *(C.O.)* the centric occlusion tracing made on the articulator; *(C.R.)* the centric relation tracing made on the conscious subject; *(A)* the tracing made under general anesthesia; *(A + C)* the tracing made under general anesthesia with curare.

more tracings were made. For the remainder of the subjects, needle point tracings were made in the second plane of the third stage of anesthesia while they were under the influence of curare.

FINDINGS

1. Eleven of the 12 subjects showed mandibular movement posterior to the posterior border position when under general anesthesia.

2. A greater increase in the separation of the jaws in the vertical dimension of occlusion resulted in a proportionate decrease in the posterior displacement of the condyles beyond the posterior border position.

3. There was no difference in the needle point tracings of patients when they were conscious and when they were premedicated with meperidine and atropine. However, records from premedicated patients were easier to obtain.

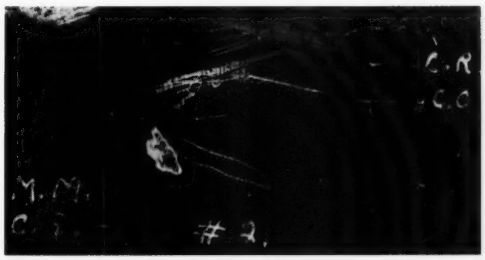


Fig. 4

Fig. 5

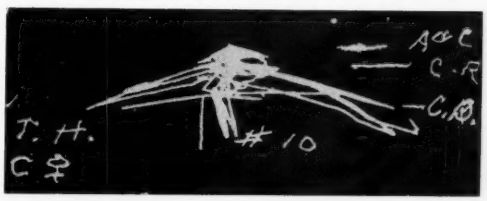


Fig. 6

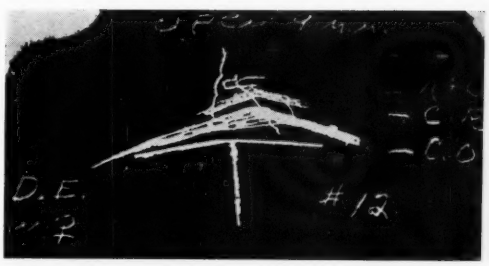


Fig. 7

Figs. 4 through 7.—More relaxation occurred in subject 2 after the anesthesia became more profound. More relaxation was obtained in subject 11 when additional thiopental sodium was superimposed upon nitrous oxide and curare. Subjects 10, 11, and 12 demonstrate that the paths of the needle point tracing became shorter as the vertical dimension was increased.

4. Stimulating the patient while recording the tracings seemingly affected the results. An example is the application of cold sterilizing solutions on and around the operative site.

5. The second plane of the third stage of anesthesia combined with smaller doses of curare was more effective in paralyzing the muscles of mastication than the excitement stage of anesthesia combined with larger doses of curare.

DISCUSSION

The lack of posterior movement in subject 8 can be explained on the basis of the plane of anesthesia and degree of separation of the jaws. The patient was in the first plane of the third stage of anesthesia, during which there is less relaxation. The amount of posterior movement can also be decreased by increasing the vertical separation of the jaws beyond the midpoint of the total vertical separation.

With subject 6 (Fig. 3), the stylus moved forward through the first three planes of anesthesia, with most of the movement occurring after the administration of curare during the third plane. The superimposition of the tracings of this subject demonstrates why three photographs were necessary for each subject.

Subjects 2 and 5 (Figs. 3 and 4), to whom curare was administered in the first plane, demonstrate how more relaxation was obtained after anesthesia became profound. Subject 11 (Fig. 5) shows that more relaxation can be obtained when the anesthesia is deepened by superimposing additional thiopental sodium upon nitrous oxide and curare.

Subjects 10, 11, and 12 (Figs. 5 through 7) demonstrate that smaller arms of the needle point tracing are obtained with paralyzed muscle than with apparently normal muscle. However, the tonus of the muscles does not affect the length of the arms of the tracings. The vertical dimension of occlusion was increased more than 2 mm. for these 3 subjects. This finding confirms the work of Posselt[1] in which he reported that the arms of the needle point tracing become shorter as the vertical dimension is increased beyond one-third to one-half of the total opening. The arms also become shorter when the jaw is moved posteriorly, which again confirms the work of Posselt.

SUMMARY

Needle point tracings were obtained from 12 conscious subjects. While these same subjects were under the influence of general anesthesia and curare, needle point tracings were again obtained. The condyles of the patients under anesthesia and curare could be moved further posteriorly than the conscious posterior border position.

CONCLUSIONS

1. Muscles are responsible for limiting posterior border movements of the condyles in the articular fossa of the human temporomandibular joint.

2. Articulators should be modified so that interferences between clutches can be removed. This applies especially to interferences found beyond the posterior border position.

Acknowledgment is made to Dr. Walter Zeit, Professor and Chairman of the Department of Anatomy, and to Dr. H. B. Benjamin, Associate Professor of Anatomy, Marquette University, School of Medicine.

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INTEGRATION OF THE SCIENCE OF OCCLUSION

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THE TERM OCCLUSION is derived from the word occlude, which means to shut or close. Therefore occlusion signifies the act of closing or bringing the teeth into contact. However, there are many biologic and mechanical factors that must be considered in order to have a clear and precise concept of the ideal occlusion.

STATUS OF THE SCIENCE OF OCCLUSION

Certain phases of dental construction do not conform to the original principle of occlusion.

To properly design occlusal surfaces of posterior teeth by some methods being used is impossible. The stock teeth supposedly designed according to a scientific principle are arranged by an empirical method. Devices to register the mandibular movements are many and of different qualifications. A great variety of articulators are used, with the condylar guides sometimes in the upper member and sometimes in the lower member and the incisal guide always in the lower member.

When a patient has for some time worn a denture that was constructed on an adaptable articulator, friction produces bright spots on the occlusal surfaces of the posterior teeth. These spots do not coincide correctly with the cuspal inclines produced in the articulator. Worn-down teeth of older people frequently produce a curve that is opposite to that obtained by means of theories with which one is familiar.

The conclusion is obvious. There must be something wrong with the theory of mandibular movements, the design of occlusal surfaces of posterior teeth, occlusion, articulators, and registering devices. Therefore, a revision of the principles is imperative.

The fault lies in the fact that none of the theories have been proved. They were put on paper and applied to practice without confirmation.

RELATING MANDIBULAR MOVEMENTS

The study of mandibular movements has been made by the static arbitrary representation of the movement without kinematic experiments. Such experiments must be made relating the movement to coordinate axes.

In mechanics, a moving object must be related to definite reference marks. The movement is determined only by mentioning the object to which it is related.

Read before the Academy of Denture Prosthetics in San Juan, Puerto Rico.

In the theory of occlusion, the movement is mathematically identified in relation to coordinate axes, the abscissa and ordinate. In practice, the abscissa and ordinate are represented by the static paths related to the head.

COMPONENTS OF THE MASTICATING APPARATUS

A study must be made using simple experimental devices representing the basic components of the masticating apparatus. These components are the activating mechanism or muscles and associated structures and the activated parts or osseous structures and the teeth.

A careful analysis of this activating mechanism reveals the direction of the different movements of the mandible. The activated parts are the lower component or mandible, the lower teeth and associated structures, the upper component or maxillae, and the upper teeth and associated structures. The upper component is static in the head and is considered as part of the activated mechanism because it becomes engaged in function with the lower component.

Therefore, the activated mechanism is composed of two parts, one upper static part and one lower movable part. The upper part is represented by the glenoid cavities and the upper dental arch, the lower part by the mandible and the lower dental arch. The meniscus is interposed between the upper and lower parts in the glenoid cavities.

The condyles and lower central incisors produce paths in their different movements that are the abscissa and ordinate to which the movement is related. These paths determine the type of movements made by the mandible.

Intermediate movable points are represented by the tips of the cusps of the lower posterior teeth that move in harmony with the condyles and the anterior teeth. The intermediate points produce paths in the upper posterior teeth that are in harmony with the paths of the condyles and the lower anterior teeth.

Therefore, movable points and paths produced by these movable points are involved. All of the movable points are in the lower part or mandible; all of the paths produced are in the upper part and are static.

MOVEMENTS OF THE ARTICULATOR

In an articulator, the condylar guidances must represent the condylar paths and the incisal guidance must represent the paths of the lower anterior teeth. These paths represent the abscissa and ordinate to which the movement is related and, therefore, must maintain their true position and relation to each other in both protrusive and lateral movements. The condylar elements or intercondylar shaft represents the condyles, and the incisal guide pin represents the lower anterior teeth.

The upper elements must be placed in one member of the articulator and the lower elements in the other member. If these elements are to be logically represented in their correct position, all paths represented by the guides must be placed in the upper member of the articulator and all movable points in the lower member. Thus, the condylar guides and the incisal guide table must be placed in the upper member, and the condylar elements and the incisal pin must be placed in the lower member.

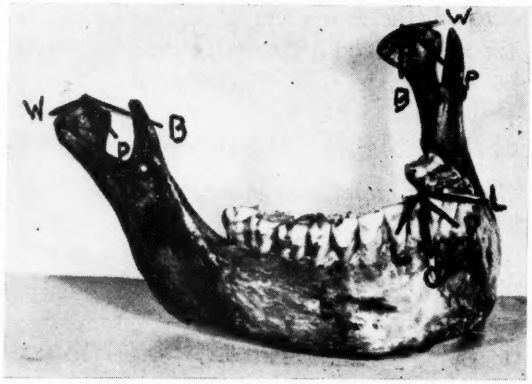

Fig. 1.—This figure is similar to Gysi's. The paths form an integral system and are not separated: *(W)* working path; *(B)* balancing path; *(P)* protrusive path; *(O)* opening movement; *(L)* lateral movements.

If the guides are arbitrarily moved from one member of the articulator to the other, will the articulator produce the same type of movement made by the mandible? The answer is definitely no because the relation of the abscissa and ordinate with which the movement is associated has been destroyed.

MOVEMENTS OF THE MANDIBLE

The mandible makes two kinds of movements: (1) movements with the teeth in contact or protrusive and lateral gliding movements and (2) movements without contact of the teeth. The circular opening movement is the one that must be considered.

The movements of the mandible form an integral system that must not be separated, and the relation of this system is established in the hinge axis. The movements have a starting and terminal position called centric relation which is established at a predetermined vertical dimension of occlusion.

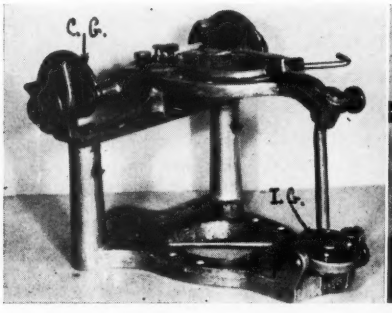

Fig. 2

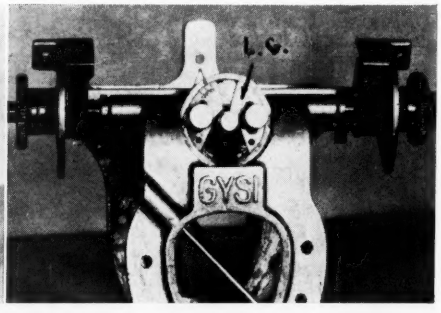

Fig. 3

Fig. 2.—The Gysi articulator. The condylar guide *(C.G.)* and the incisal guide *(I.G.)* are in the lower member.

Fig. 3.—The lateral condylar guide *(L.G.)* is in the upper member of the Gysi articulator.

Centric relation is established by means of a needle point tracing, using a central bearing point. The stylus tracings and the hinge axis depend upon each other for precision. Without the location of the hinge axis, a true needle point tracing cannot be made.[1] The tracings may be used to verify the location of the hinge axis.

ANALYSIS OF THE PROBLEM OF OCCLUSION

I have previously reported an analysis of these problems. The findings indicated that the mandible does not make circular movements but that its motion when the teeth are in contact is elliptic.[2] The center of curvature is below the

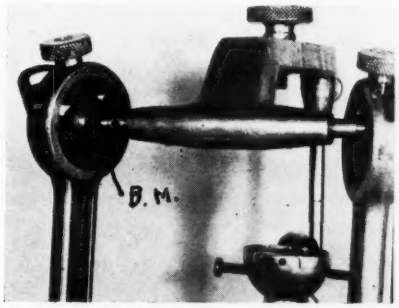

Fig. 4.—The Bennett movement *(B.M.)* is produced in the upper member of the Hanau articulator.

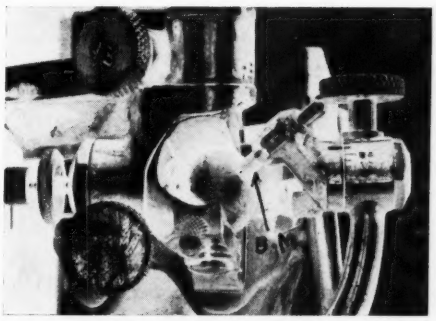

Fig. 5.—In the precision coordinator, the condylar protrusive and lateral guides are placed in the upper member. The Bennett movement *(B.M.)* is produced in the lower member. The broken-axis adjustment destroys the accuracy of the protrusive movement.

occlusal plane, not above as is generally believed. The only circular movement is the opening movement.

If the guides in an articulator are arbitrarily moved from one member to the other, the articulator will make an entirely different type of movement.[3,4] Therefore, a denture or any other prosthetic restoration made on an articulator that does not have its components properly related will not function correctly in the mouth.[5] The restoration will produce abnormal frictional stresses that may cause resorption of the residual ridges, formation of periodontal pockets, etc.

Gysi's[6] concept of mandibular movements was correct at the beginning of his study. One of his illustrations shows that all the moving points are in the mandible and that all the paths are related to the upper part and are static (Fig. 1).

Yet, when he designed his articulator, he placed the protrusive condylar guides and the incisal guide table in the lower member (Fig. 2) and the lateral condylar guides in the upper member (Fig. 3). Thus, the Bennett movement is in the upper member as it is in the Hanau articulator (Fig. 4).

The protrusive and lateral condylar guides are placed in the upper member in Terrell's precision coordinator, but because of its design, the Bennett path is in the lower member. The broken axis adjustment in this articulator that is intended to reproduce the upward or downward direction of this path destroys the accuracy of the protrusive path (Fig. 5).

This arbitrary location of the guides in one member or the other of the articulator leads to inaccurate reproduction of mandibular movements.

SUMMARY

The status of the science of occlusion is not satisfactory. Therefore, a revision of the principles of occlusion was made.

This revision revealed that the theories had not been proved but were applied to practice without experimental verification. A series of facts are known, but they are not correctly related to each other by a general law. Therefore, this is not a science. Knowledge of a single fact not related to any other or of many facts with no mutual relation does not attain the meaning of science.

Science is a number of systematic judgments that are not contradictory to each other and are experimentally verified. Judgment is the correlation between a question and an answer. All judgments must form a system of concepts that will not contradict but will complement each other. These concepts must be related by a general law that will permit us to understand all facts in our possession. The general law must be a law of causality.

In the reproduction of the circumstances under which the act is taking place, the conditions must be faithfully reproduced. This is obtained by establishing a symmetery of causes. Therefore, symmetry of causes will persist in the effects.

Observation and analysis of the mandibular function show that one is dealing with movable points and paths produced by these moving points. All of the movable points are in the lower part or mandible, and all of the paths are in the upper part or maxillae and are static.

These elements must be logically represented in the articulator. Therefore, all of the paths must be placed in the upper member and all of the movable points must be in the lower member of the articulator. If this relation is altered, the articulator will not produce the same movements as are made by the mandible.

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DIMENSIONAL STABILITY OF ACRYLIC RESIN DENTURES
Clinical Evaluation

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MANY VARIABLES which influence dimensional changes of acrylic resin dentures in the mouth are beyond the scope of control in a clinical study. However, certain factors which are mainly responsible for the changes in a laboratory evaluation have been studied. This constant search for a better denture-base material has led to some standardization of acrylic resins in the dental profession. However, in the final analysis, a denture-base resin is evaluated in use, under conditions existing in the mouth. The purpose of this article is to present information regarding the degree of dimensional change occurring in dentures and the significance of this change in clinical fit.

The literature on the subject of dimensional change in complete dentures has been covered by Woelfel and Paffenbarger.[1]

Recent clinical studies of dimensional changes in dentures indicate the correlation of clinical fit and dimensional change. Mowery and colleagues[2] report that dentures may change dimensionally but be successful clinically. The over-all variability observed by Mowery, despite precise measurements, was so great that more clinical data are needed to arrive at definite conclusions.

The questions which must be answered are: (1) How much change is required in a denture to affect the fit in the mouth? (2) How much dimensional change of acrylic resin dentures in use is tolerable to the tissues? (3) Is the denture fit the main factor in evaluating a denture-base resin? (4) Are tissue changes taking place in the mouth because of, or in spite of, the change in the resin? (5) Do any changes in denture bases cause pressure which might increase tissue resorption and trauma to the underlying bone? (6) How important is accuracy in curing to the success of complete dentures?

PROCEDURES

A total of thirty-three clinical dentures, designated as group A, were constructed using a heat-cured methyl methacrylate resin. Group B was composed of thirty-one clinical dentures constructed of an autopolymerizing acrylic resin; these were measured by the same operator. The dentures were prepared by use of a

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casting technique in a flexible mold. It was thought that less stress would be induced in dentures with this cold-curing technique because (1) the resin is cured at a lower temperature, thereby reducing thermal expansion, and (2) the resin is not confined during the curing, thereby reducing stresses that might build up by pressure in a closed mold.

METHODS OF TESTING

Changes in group A were recorded at the same interval as in group B and were clinically evaluated on a comparative basis. Three test methods were used to evaluate the clinical correlation of groups A and B: (1) a linear microscopic measurement, (2) the perceptible change seen on the initial cast, and (3) an observation of fit in the mouth.

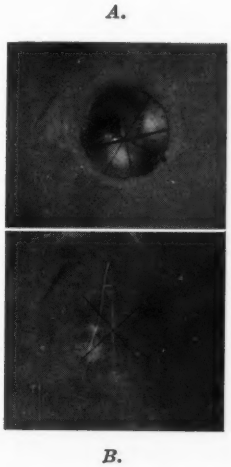


Fig. 1.—Pins with minute crosses on the heads are used as points of measurements. *A*, A machine-scribed cross viewed microscopically. *B*, A pinhead cross intaglio on the denture viewed microscopically.

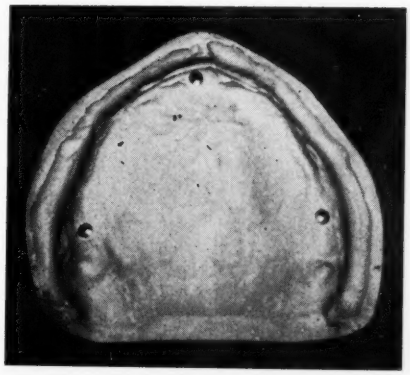


Fig. 2.—Pins are located on the cast in the molar and incisor region.

LINEAR MICROSCOPIC MEASUREMENT

Linear dimensional changes were measured using a Gaertner microscope with readings accurate to 1/10,000 inch. Replicate readings were made at 1/3,000 inch. Pins having minute crosses on the heads were employed as points of measurements on the cast (Fig. 1). The impression of the machine-tooled crosses was clearly visible on the cured dentures.

Three pins were cemented into the artificial stone cast, two in the molar region and one in the incisor region (Fig. 2). The legs of the triangle thus formed were recorded. The distance from molar region to molar region was represented by x_1, from the left molar region to the incisor region by x_2, and the remaining side by x_3.

Plaster occlusal keys were made to serve as mounts for the purpose of measurements on the dentures (Fig. 3). Subsequent linear dimensional changes in the denture were recorded after curing and after insertion for 1 day, 1 week, 1 month, and 3 months.

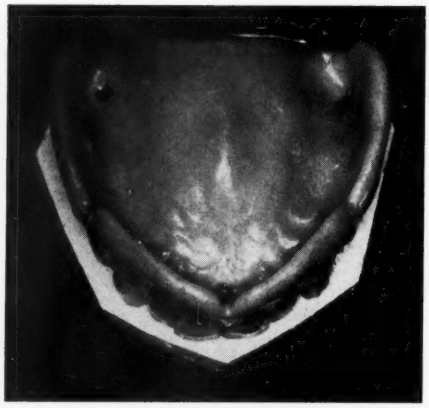


Fig. 3.—A plaster key employed to orient the two measuring points in the same horizontal plane.

From the pilot readings on a denture, it was observed that an error was created if the two measuring points were not placed in one horizontal plane. A two point levelometer devised to measure the angle of the tilt from horizontal was employed to avoid this error (Fig. 4). The dentures were mounted on the plaster key so that the measuring points were brought to one level. Any possible linear error was determined trigonometrically.

PERCEPTIBLE CHANGE ON THE INITIAL CAST

Artificial stone was poured in each of the dentures before the preliminary insertion in the mouth. All undercuts on the flanges were relieved before the casts were made. A constant water:stone ratio of 1:3.5 by volume was maintained for all casts, and the mix was hand spatulated. The casts were trimmed and stored in a chamber at a constant temperature of 37° C. in a relative humidity of 32 per cent.

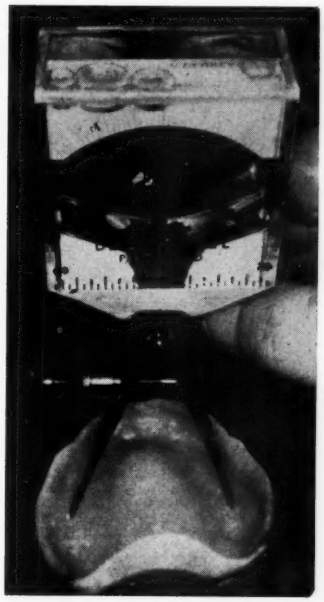
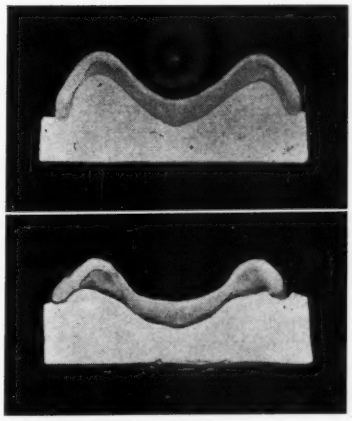


Fig. 4.—A two point levelometer is used to orient the two measuring points in the same horizontal plane.

The existing space between the denture and cast was measured at the end of a 3 month period. The points of measurement were at the midline of the palate in the upper and at the lingual flange in the lower dentures. The casts were cut away 2 cm. from the distal border of the denture, the dentures were seated, and the existing space was graded by a wire gauge according to the measurements (Fig. 5).

A.



B.

Fig. 5.—*A*, The denture fits the cast accurately before use. *B*, After 3 months of use, the discrepancy is measured with a wire gauge.

Fig. 6

Fig. 10

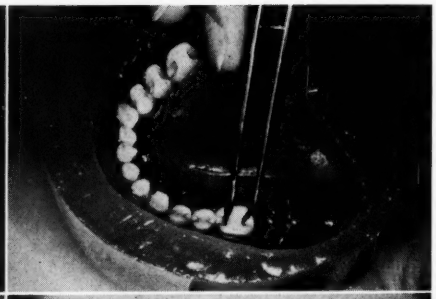


Fig. 7

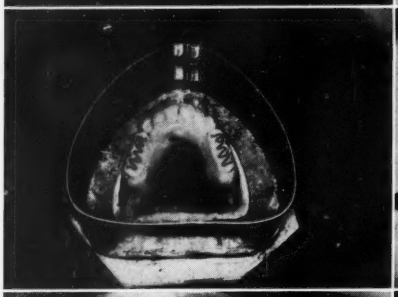


Fig. 11

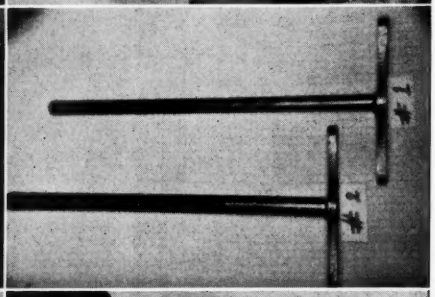


Fig. 8

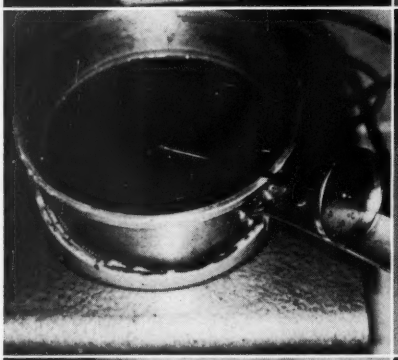


Fig. 12

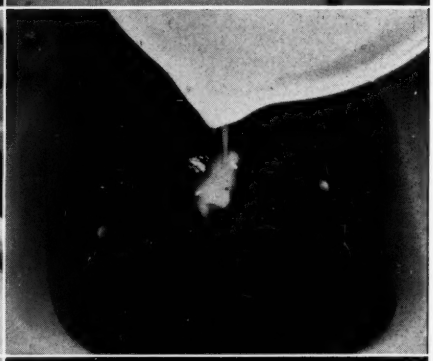


Fig. 9

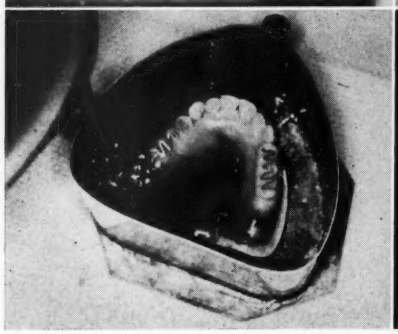


Fig. 13

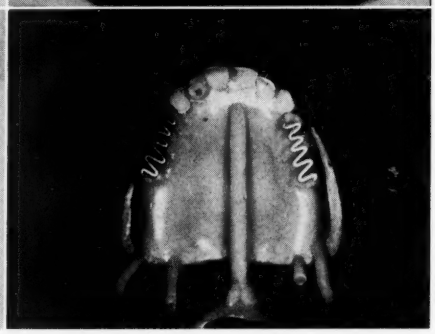


Fig. 6.—The keys in the cast permit proper seating of the cast back into the flexible mold.

Fig. 7.—The wax denture is boxed in a stainless steel ring.

Fig. 8.—The reversible hydrocolloid material is heated in a water bath until it is uniformly melted.

Fig. 9.—The reversible hydrocolloid material is poured into the prepared ring.

Fig. 10.—After the boilout, the teeth are replaced in the irreversible hydrocolloid mold.

Fig. 11.—Sprue holes and an air vent are made in the mold with cork borers.

Fig. 12.—The acrylic resin is poured into the mold through a sprue hole.

Fig. 13.—The denture is separated from the mold after curing.

OBSERVATION OF FIT IN THE MOUTH

The fit of the dentures in the mouth was tested at the end of 3 months. The clinical fit was judged by applying finger pressure at three different points, two on the occlusal surfaces of the first molars, on both sides, and one on the incisal edge of the central incisors, at the midline.

The forces were directed vertically, with a slight buccal tilt on the molars and a labial tilt on the incisors. The amount of pressure and the direction of the forces depended on the judgment and skill of the dentist and thus were subject to possible error.

Five attempts were made to dislodge a denture before a final value was recorded. The clinical fit of each denture was graded as good, fair, and poor, depending on the points of dislodgment and the patient questionnaire.

PROCESSING OF HEAT-CURED DENTURES

The waxed dentures were flasked in Hanau flasks with plaster of Paris. An alginate liquid was used as a separator for both groups. The heat-curing resin was a standard cross-linked monomer and a polymer.* A monomer : polymer ratio of 1 :3 by volume was used, as recommended by the manufacturers. All heat-cured dentures were cured for 8 hours at a constant temperature of 165°F.

CURING OF AUTOPOLYMERIZED DENTURES

Three indentation keys were made on the lateral walls of the cast (Fig. 6) to facilitate the proper seating of the cast back into a prepared flexible mold. The waxed denture and the cast were boxed in a stainless steel ring over an asbestos sheet (Fig. 7) and sealed with molten sticky wax. Water was poured in the ring to test the seal and to soak the cast for a minimum period of 10 minutes.

A reversible duplicating hydrocolloid material† was heated in a water bath until it was evenly melted (Fig. 8). It was cooled to 52° C, poured into the prepared ring to the top (Fig. 9), and allowed to gel for 1 hour at room temperature.

After gelling, the mold was removed from the ring and the cast was separated. The boilout was accomplished by immersion in boiling water, and the teeth were reset into the prepared mold (Fig. 10). The cast was painted with an alginate liquid foil substitute.

Just before the cast was embedded into the duplicating mold, a sprue hole was made in the center of the denture using No. 2 cork borers. Four air vents were created in the mold at the distal border of the denture by means of a narrower cork borer, No. 1 (Fig. 11).

An autopolymerizing resin‡ with a cross-linked monomer and polymer was mixed with a special technique in the manufacturer's ratio of 7 :10 by volume. The resin was poured in a liquid state until it was seen coming out of the air vents (Fig. 12).

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*Vitalon
†Perflex.
‡Acrylcast.

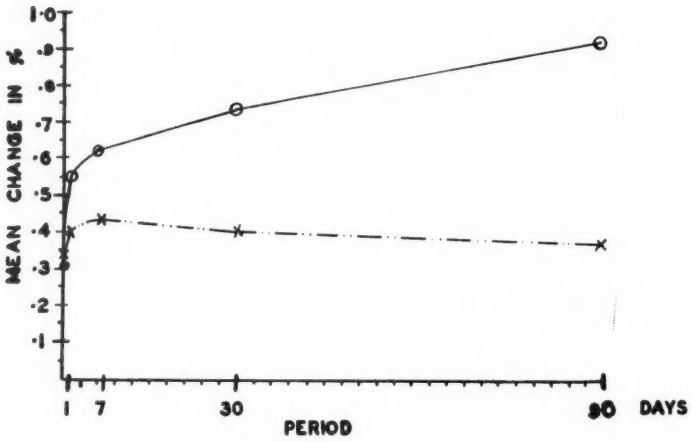

Fig. 14.—Linear dimensional changes of side x_1 after processing of dentures and in function: (· · —— · ·) heat-curing resin; (——) autopolymerizing resin.

The dentures were bench cured in the duplicating mold for ½ hour at room temperature. The hydrocolloid material was cut apart, and the denture was post-cured on the cast for ½ hour in a dry heat oven at 72° ± 2° C. (Fig. 13).

EXPERIMENTAL RESULTS AND DISCUSSION

The comparative values of the two resins were determined by a statistical method. Since the frequency distribution curves of the population were unknown, the method of choice for the comparison was restricted to the Fisher sign test. The two groups were tested for significant differences by taking group A as the standard and calculating the mean and the variance for the group as a whole and for the different time periods.

The linear curing shrinkage of all dentures of the heat-cured group (A) was 0.34 per cent, whereas that of the autopolymerized group (B) was 0.31 per cent when measured from molar region to molar region. The variability from one den-

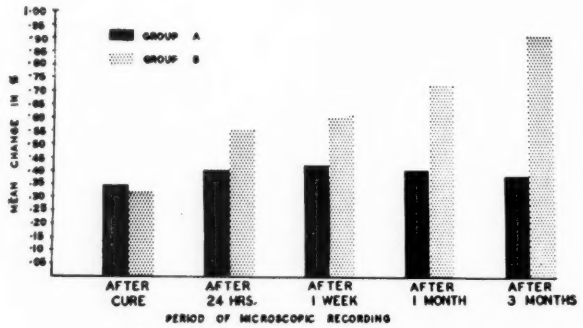

Fig. 15.—Histogram illustrating the linear dimensional change, comparing groups A and B in dimension x_1.

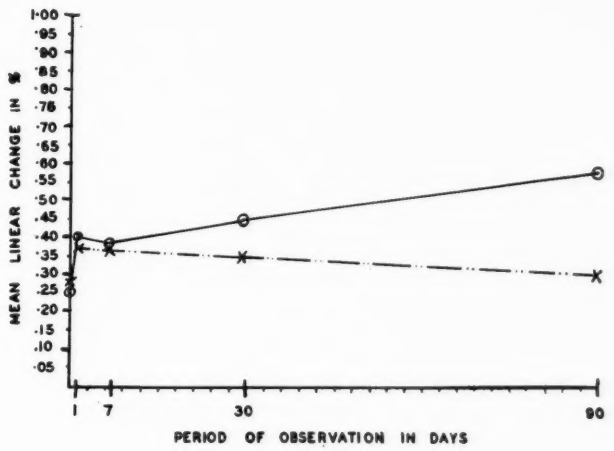

Fig. 16.—Linear dimensional changes of the perimeter after processing of dentures and in function: (· · —— · ·) heat-curing resin; (——) autopolymerizing resin.

ture to another was greater than expected and was in agreement with the results of Mowery. However, this difference was within a range of ± 0.10 per cent and was present in both groups.

The curing shrinkage of the upper dentures of the heat-cured group was 0.31 per cent, in comparison to 0.26 per cent for the autopolymerized group. No significant difference in the curing shrinkage was noted betwen groups A and B when treated statistically by the methods employed.

The linear dimensional change after 24 hours of use in the mouth showed a significant difference between groups A and B. Group A had a linear change of —0.40 per cent, whereas in group B it was —0.55 per cent. The greater change in the autopolymerized group after 24 hours of use may be due to less thermal curing shrinkage and hence less stress relieved instantaneously. However, after 1 day, the remaining stresses are relieved in greater masses than in heat-cured resin.

A maximum amount of shrinkage was noted in the heat-cured group when measured after 1 week of use. The dentures showed a gradual expansion. How-

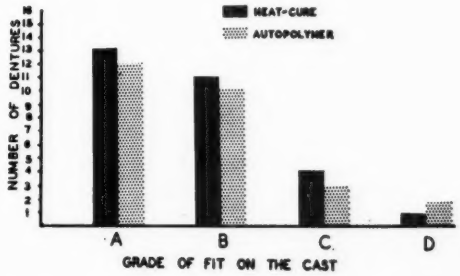

Fig. 17.—Histogram illustrating the cast adaptation of the heat-curing compared to the autopolymerizing resin dentures after 3 months.

ever, after 1 week, this expansion failed to compensate for the curing shrinkage. In general, the greatest dimensional change occurred during the first month and leveled off at the end of 3 months. The dentures in the autopolymerized group continued to shrink throughout the entire testing period of 3 months (Fig. 14). The difference was statistically significant when compared with the heat-cured group. This continuous shrinkage of the autopolymerized denture group over a period of 3 months may be due to the greater volume of monomer employed in the acrylic resin mix. The ratio of the polymer of the new autopolymerizing resin was changed for study in the laboratory evaluation.

The anteroposterior linear measurements of the dentures were also obtained to find the true linear change. The curing shrinkage was different when the results of all three sides, x_1, x_2, and x_3, were computed as compared to the single side, x_1 (Fig. 15). The curing shrinkage of the perimeter of the three sides of group A was 0.28 per cent, whereas that of group B was 0.25 per cent (Fig. 16). More consistent readings were obtained for side x_1 than for sides x_2 and x_3 in both groups.

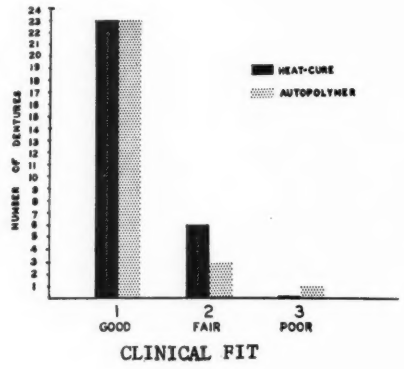

Fig. 18.—Histogram illustrating the quality of fit of the heat-curing and the autopolymerizing resin dentures as compared clinically.

The results on cast adaptation of groups A and B after 3 months of use showed almost an equal distribution in the four grades (Fig. 17). No perceptible space was observed between the posterior border of the cast and the denture for thirteen dentures of group A and twelve dentures of group B. A presence of 0.25 mm. space or less was recorded in eleven heat-cured dentures and ten autopolymerized dentures. A presence of 0.5 mm. of space was noted in six heat-cured dentures and five autopolymerized dentures. Only one heat-cured denture and two autopolymerized dentures had a space of 1 mm. Although the heat-cured dentures recorded better cast adaptation, the over-all results were not significantly different to show the superiority of one resin over the other.

CLINICAL FIT

The autopolymerized resin dentures had almost the same degree of clinical fit, on an average, as the heat-cured dentures when examined after 3 months (Fig. 18).

Twenty-three dentures of both groups were classified as good. Six heat-cured dentures were classified as fair as compared to three autopolymerized dentures, and only one autopolymerized denture was classified as poor.

Four dentures in each group could not be tested for clinical fit and cast adaption because the patients failed to return for the 3 month visit.

CONCLUSIONS

The clinical fit of autopolymerized dentures was equally as good as that of heat-cured dentures, even though the magnitude of linear dimensional changes of the autopolymerized dentures after 3 months of use was greater than in the heat-cured group.

The average processing shrinkage of autopolymerized dentures after ½ hour of postering at 72° ± 2° C. was less than that of heat-cured dentures, but the difference was statistically insignificant.

The heat-cured acrylic resin dentures reached a maximum change in the negative direction in 1 week. After that, the change gradually approached the initial value of the curing shrinkage. The autopolymerized acrylic resin dentures continued to change in the negative direction throughout the entire 3 month period.

I wish to express my sincere appreciation to Dr. Irving R. Hardy, Professor Emeritus of Tufts University, School of Dental Medicine, for his guidance and counsel, and to Austenal, Inc., for equipment and mateirals provided to carry out this work.

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A STUDY OF HINGE AXIS DETERMINATION

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THE PHYSIOLOGIC ACTION of the temporomandibular joint was described in *Gray's Anatomy* in his earliest editions. In 1921, McCollum "discovered the first positive method of locating the hinge axis."[1] In 1934, "in cooperation with Stuart, he [McCollum] developed the first instrument capable of duplicating these exact mandibular movements."[1] The clinical demonstration of such an axis was considered a boon to dentistry. By obtaining its location, it became possible to transfer, onto an articulating frame, the rotational centers of the patient's mandibular movements. These rotational centers could be located in both the vertical and lateral positions.

With this concept, it is considered possible to increase or decrease the vertical dimension on the articulator within the limits of the opening arc of movement, without changing the centric relation. Prior to the development of the hinge axis concept, any increase or decrease made in the vertical dimension had required that a new centric relation record be made to safeguard against a possible change in this positional relation record. In addition, it now became possible to more accurately reproduce the rotational centers arcing on the horizontal plane.

OPINIONS OF OTHER INVESTIGATORS

The assumption that a single hinge axis rotational point exists was concurred in by other investigators. Kornfeld[2] stated, "The hinge axis can be located accurately by trial and error . . . ." Granger[3] stated, "There is however, one, and only one, position in which the hinge axis is constant to both the mandible and maxilla." Sloane[4] stated, "The mandibular axis is not a theoretical assumption, but a definitely demonstrable biomechanical fact. It is the axis upon which the mandible rotates in an opening and closing function when comfortably, not forcibly, retruded."

Thompson[5] was convinced of the presence of a hinge axis and even "suggested to my preceptors a change in the face-bow which would permit the moving of one condyle indicator at a time, without loosening the toggle clamp."

However, in the minds of later investigators, some doubt existed as to whether or not a *single* terminal hinge axis existed or if hinge axes existed at all.

Collett[6] recognized that there is not complete agreement on the existence of the hinge axis. Levao[7] doubts that a hinge axis, granting that one is present, can be registered because "the presence of the clutch attachment on the mandible prevents its closure to a contact relationship." Kurth and Feinstein[8] stated, "With the

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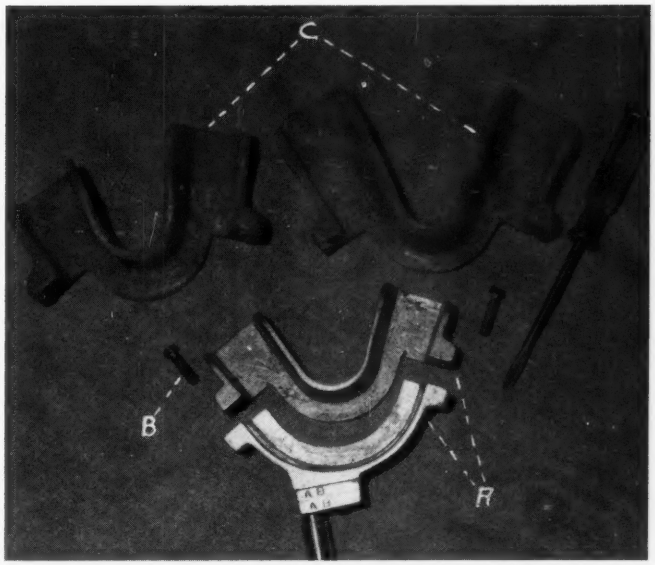


Fig. 1.—The mandibular clutch assembly: *(A* and *B)* the stock metal clutch; *(C)* the acrylic resin extensions for the clutch to make it fit the subjects.

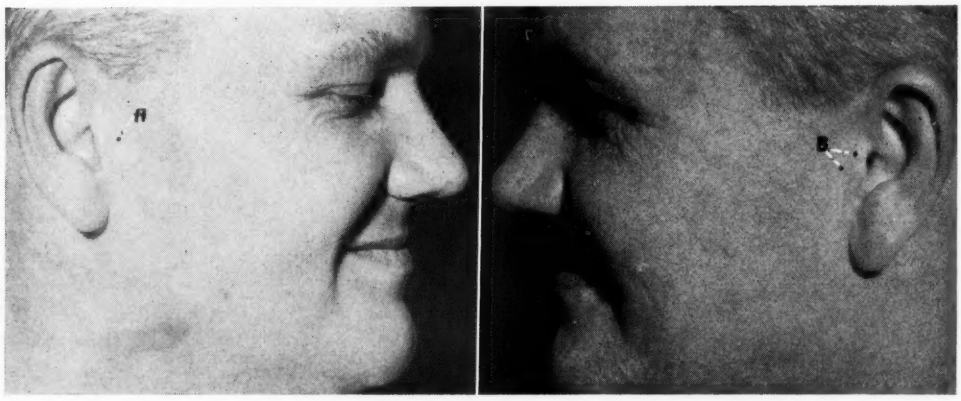
aid of an articulator and a working model, we have demonstrated that more than one point may serve as a hinge axis. Thus we conclude that an infinite number of points exist which may serve as hinge points."

OBJECTIVES OF THIS STUDY

In view of this difference of opinion, it was felt that a re-examination of the problem should be undertaken. Two points were investigated: (1) whether there is a terminal hinge axis and (2) if so, whether or not only one exists.

A. *B.*

Fig. 2.—*A,* Two hinge axis points were located on the right side of the subject 2. *B,* A single point was found on the left side.



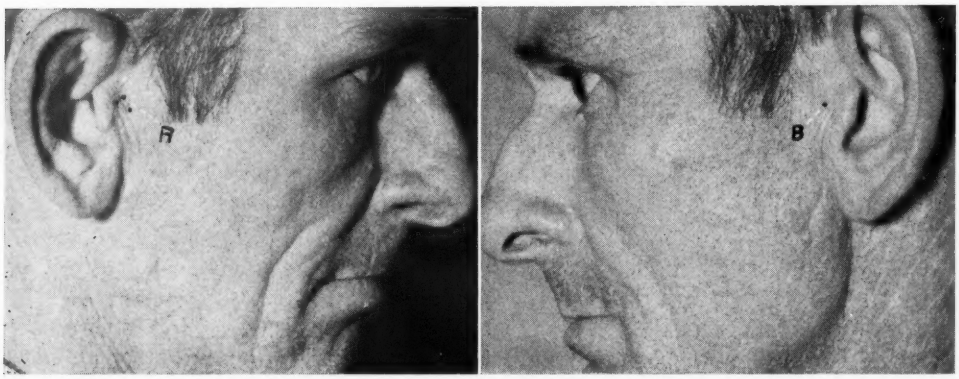
A. *B.*

Fig. 3.—*A*, A single point was located on the right side of subject 7. *B*, Two points were found on the left side.

All subjects were employees or domiciliary members of the Veterans Administration Center, and all except one were men between the ages of 45 and 65. All subjects had either a relatively complete complement of maxillary and mandibular teeth or were completely edentulous in the maxillary arch with some mandibular teeth present.

METHOD, MATERIALS, AND RESULTS

To remove the slightest possibility of a prejudicial evaluation of whether or not a terminal hinge axis point had been located, the evaluation was made by neutral observers. In other words, the investigators located what they deemed to be a terminal hinge axis but the final decision as to whether or not a terminal hinge axis point had been located was left to the disinterested observers.

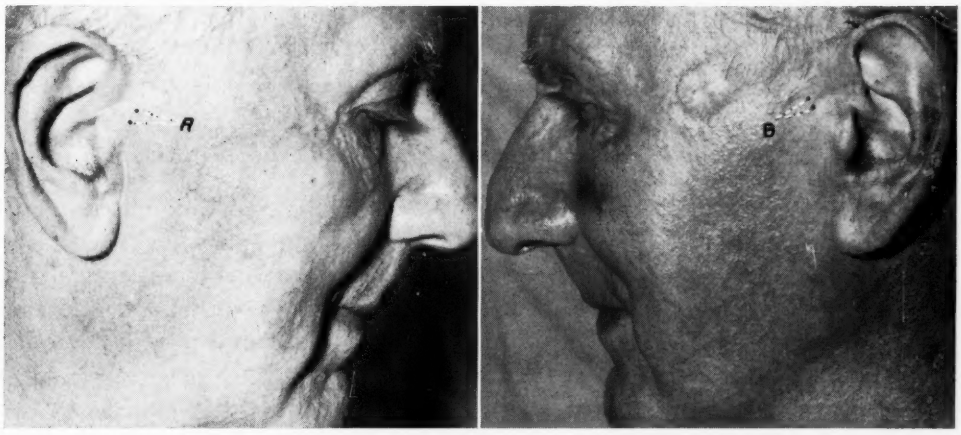


A. *B.*

Fig. 4.—*A*, Three hinge axis points were found on the right side of subject 9. *B*, A single point was found on the left side.

A Hanau adjustable hinge axis face-bow equipped with a stock clutch tray was used. The stock clutch tray was inadequate in many mouths because of its insufficient length. To overcome this difficulty, acrylic resin attachments were made which could be fittted onto the anterior section of the stock clutch (Fig. 1). A zinc oxide–eugenol paste, which upon setting became hard, was used to attach the clutch to the mandibular teeth. If the subject was wearing a mandibular removable partial denture, it was left in position in order to afford additional support and retention.

With the clutch in position, after the paste had set thoroughly, an arbitrary location of the condyle was made. This was done to determine the approximate location for the initial setting of the arms of the face-bow. The anterior transverse bar part of the face-bow and the side face-bow arms were next placed in position. To avoid overweight on either side, both side arms of the face-bow were attached before an attempt was made to locate a terminal hinge axis.



A. *B.*

Fig. 5.—*A* and *B*, Two hinge axis points were found on the right and left sides of subject 13.

It was found to be quite difficult, if not impossible, for one person to train the patient to make the learned hinge movement and at the same time observe movement or lack of movement of the stylus used to locate the hinge axis. To overcome this difficulty, one investigator concerned himself with directing the patient to make a hinge axis movement while the other investigator concentrated on the adjustment of the stylus to the point where the rotational center became fixed. The investigators would then alternate their roles, and the other investigator would determine when a hinge axis point had been located. When both investigators had been satisfied that a hinge axis point had been located, neutral observers were asked to evaluate the result. In all but 2 subjects, the neutral observers were of the *unanimous* opinion that the point so located represented a hinge axis point. In the 2 cases in question, the majority of the neutral observers agreed that the point located represented a hinge axis point.

TABLE I

SUBJECT NUMBER	SEX	HINGE AXIS POINTS LOCATED		PREMEDICATION	NUMBER OF OBSERVERS CONCURRING	
		RIGHT SIDE	LEFT SIDE		RIGHT SIDE	LEFT SIDE
1	F	2	1	No	3	3
2	M	2	1	No	3	3
3	M	1	1	No	3	3
4	M	1	1	No	3	3
5	M	1	1	No	3	3
6	M	1	1	No	3	3
7	M	1	2	No	4	4
8	M	2	3	No	3	4
9	M	3	1	No	5	4
10	M	1	1	Yes	4	4
11	M	1	1	No	5	5
12*	M	2*	1	No	4*	5
13†	M	2†	2	Yes	5†	5
14	M	1	2	Yes	3	3

*Two hinge axis points were located on the right side: (1) upper hinge axis point—two observers concurred in location, two observers stated "very close"; (2) lower hinge axis point—four observers concurred in location.

†Two hinge axis points were located on the right side: (1) upper hinge axis point—four observers concurred in this location, one observer did not concur; (2) lower hinge axis point—five observers concurred in this location.

Next, to determine if there was any other point or points which could be located as representing a hinge axis point, one investigator concerned himself with the opening and closing movement made by the subject, while the other investigator moved the stylus in various other positions in an endeavor to locate other hinge axis points if they existed (Figs. 2 to 5).

During this part of the investigation, it was impossible to locate a hinge axis point on some subjects. We attributed this to tension on the part of these subjects. These subjects were premedicated with proclorperazine* before undertaking the procedure again. When used, the dosage was 10 mg. on the night prior to the day on which the investigation was to occur, 10 mg. before breakfast, and 10 mg. before lunch, prior to the time of the tests. Proclorperazine acts as a muscle relaxant and tends to overcome "mild and moderate mental and emotional disturbances" such as are frequently encountered in dental practice. All of the premedicated subjects became more amenable to the instruction and guidance given by the investigators on opening and closing the mandible.

The findings of this investigation are shown in Table I.

SUMMARY

1. An investigation was conducted on 14 subjects to determine if there is a terminal hinge axis and, if so, whether more than one hinge axis point can be located.

*Compazine.

2. Neutral observers were used for making the final decision as to whether or not a hinge axis point had been located.

3. No completely edentulous patients were used in the investigation.

4. Premedication was used on 3 of the subjects because of tension.

5. A two man team was used to determine the location of the hinge axis points.

6. Six subjects had a single hinge axis point on both the right and left sides. Five subjects had a single hinge axis point on one side and double hinge axis points on the opposite side. One subject had double hinge axis points on both sides. One subject had three hinge axis points on one side and a single hinge axis point on the opposite side. One subject had two hinge axis points on one side and three hinge axis points on the opposite side.

7. Only 42.8 per cent of the subjects exhibited a single hinge axis point on both the right and left sides.

CONCLUSIONS

1. In 57.2 per cent of the subjects in this investigation, more than one condylar hinge axis point was located on either one or both sides.

2. These findings indicate that, since multiple condylar hinge axis points were located, the high degree of infallibility attributed to hinge axis points may be seriously questioned.

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RELINING IMMEDIATE DENTURES UTILIZING CEPHALOMETRICS

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RELINING OF CORRECTLY MADE DENTURES is not an impossible task. However, it is not something that can be done in a hurry or slighted in any way. The time required for relining dentures properly is approximately one-half of that consumed in building new dentures.

The palatal vault can be used as a guide for repositioning the upper immediate denture when it needs relining. This part of the mouth does not change significantly even though the residual ridges may shrink severely. Palatal relief should not be used except over a torus palatinus, if one exists. Thus, a greater area of contact is made, and a more accurate guide to the correct position of the denture is available.

To use the palate as a guide to the determination of the denture position, the temporary relining material must not be permitted to extend onto the palatal vault, and the denture must not be allowed to follow the residual ridge shrinkage up and back.

TEMPORARY RELINING OF IMMEDIATE DENTURES

Immediate dentures should be relined with a temporary material 3 weeks after insertion and again in 2 to 3 months. The upper denture is treated first. The relining material is placed in the denture only where tissue shrinkage has occurred and around the borders. No new material is placed on the palatal area. The denture is inserted in the mouth with enough pressure to carry the key part of the denture, the palate, into place. The pressure should be upward and forward to fit the denture snugly against the palate and rugae. These tissues will have changed little since the surgical procedures for the immediate denture. If the denture is positioned properly, the anterior teeth will be back in their original position.

There is no choice but to follow the shrinkage of the denture foundation with temporary relining of immediate lower dentures. A reduction of the vertical dimension of occlusion is likely to occur. Any healed part of the lower ridge may be used as a guide to re-establish the occlusion. The relining material is added only in the region of the recent extractions and to the borders of the denture. When most of the lower ridge is healing from multiple extractions, the entire alveolar groove and labial flange are relieved before placement of the relining material. In this manner, it is possible to guide the lower denture into proper occlusion when the mandible is in centric relation.

FINAL RELINING OF IMMEDIATE DENTURES

In some patients tissues heal rapidly, in others slowly. If a cortical layer of bone can be seen in a roentgenogram, the final relining may be completed. If the cortical layer is not readily seen, the relining should be postponed for a longer time.

Corrections in certain factors are made at the final relining of the dentures: (1) the fit of the dentures, (2) the vertical dimension of occlusion, (3) orientation of the occlusal plane, and (4) the occlusion. The fit of the dentures is corrected by making new impressions. The vertical dimension of occlusion and the orientation of the occlusal plane are corrected by the use of cephalometrics.[1] The occlusion is corrected in 7 to 10 days after the refitted dentures have been worn by the patient.

ESTABLISHING THE VERTICAL DIMENSION OF OCCLUSION

A lower preliminary impression is made in irreversible hydrocolloid, and a cast is poured of quick-setting plaster. A baseplate of either heavy shellac or quick-curing acrylic resin is adapted to the cast, and an occlusion rim is built on the baseplate.

The occlusal rim is tried in the mouth with the upper denture and trimmed to a height slightly greater than the estimated vertical relation of occlusion. The occlusion rim is warmed and inserted in the mouth, and the patient is instructed to close the jaw with the mandible in its retruded position. The wax is chilled, the occlusion rim and upper denture are removed, and both are temporarily mounted on a hinge articulator. Thus, a known distance is established between the ridges on the articulator. This distance is soon to be recorded on a lateral head roentgenogram.

A piece of relief chamber metal (lead) is luted to the buccal surface of the occlusion rim on the side which will be nearest the cassette. The relief metal is approximately ¼ by 1 inch in size and two or three notches are cut about ¼ inch wide and ⅛ inch deep on its upper side. The notches ensure accuracy in matching the mandibular movement to be recorded on the tracing of the roentgenogram. A straight 1 inch piece of wire (paper clip) is embedded parallelly with the occlusal plane of the occlusion rim and above the metal marker.

The upper denture and lower occlusion rim are removed from the temporary relationship on the articulator and inserted in the patient's mouth. The lower occlusion rim is firmly secured by denture adhesive. The patient is oriented in the chair so that the Frankfort plane (from the porion to the base of the orbit) is parallel with the floor.

The cephalometer is adjusted to the head (Figs. 1 and 2), and a roentgenogram of 4 seconds' exposure is made with the upper denture and lower occlusion rim in contact (Fig. 3). The exposure time may vary with different patients. The vertical dimension is the same as on the articulator mounting.

The first cassette is removed from the holder, and the second cassette is inserted. The timer switch is depressed for 2.5 seconds of a 4 second roentgenogram. The upper denture is removed from the mouth, and a small amount of water (1 to 2

teaspoons) is placed in the mouth. The patient is instructed to swallow the water upon a given signal. The signal is given immediately. The patient must swallow the water during the remaining 1.5 seconds of exposure time.

The upper denture is removed during the second roentgenogram to permit normal deglutition. The mandible can follow its normal path of closure uninhibited by the proprioceptive response which might result from contact between the occluding surfaces. The roentgenograms are developed (Fig. 4).

RATIONALE FOR THE USE OF DEGLUTITION

Swallowing is a frequent, rhythmic, and unstrained function for every individual. Sometimes swallowing is initiated by conscious thought; however, it usually is an involuntary (reflex) action.

The involved musculature has had a lifetime of training in the amount of mandibular closure necessary for swallowing. Since the natural teeth contact during deglutition,[2,3] erupting teeth are guided into this position of contact by constant usage. Harris[4] states, "There is only one centric occlusion." Since this is also functional occlusion, it should be established by muscles in function.

The mandibular musculature determines the correct vertical dimension of occlusion for natural teeth. When this information is recorded cephalometrically and denture teeth are arranged at this height, the jaws are restored to their correct vertical relation. The rest position of the mandible is not important here, since it is not a functional position. The important factor is to determine how much functional interarch space exists, so that the denture teeth may be arranged in occlusion within this distance.

ROENTGENOGRAPHIC TRACINGS

A sheet of "glass" paper or heavy acetate paper is attached to the first roentgenogram by cellophane tape or paper clips. A drawing is traced of the cranial outline, facial profile, sella turcica, orbit, pterygomaxillary fissure, nasal spine, basal bone of the maxillae including the nasal spine, outline of the mandible, key ridges of the maxillae, occipital condyle, outline of the notched lead marker, and occlusal plane marker (Fig. 5). Enough other detail is drawn to permit an accurate matching of the same structures when the tracing is superimposed on the second film.

The tracing is removed from the first film, matched with corresponding structures, and fastened to the second film. The highest position of travel of the lead marker during swallowing is drawn on the tracing (Fig. 4), and the tracing is removed from the second film.

The outline of the lead marker at its height of travel as drawn on the tracing is superimposed on the marker in the first film. The tracing is fastened to the first film with the markers matching, and the outline of the mandible in its new position is drawn. The tracing now contains two outlines of the mandible. The tracing is removed from the first film, and the following lines are drawn (Fig. 6): (1) from the center of the sella turcica to nasion (cranial base plane), (2) from nasion to gnathion for each mandible (facial plane), (3) from pogonion to gnathion for each mandible (mandibular plane), (4) from the center of the sella turcica to the

gnathion on the corrected mandibular position (y axis), and (5) from the nasion to the occipital condyle (the Bolton plane).

A line is drawn from the center of the sella turcica perpendicularly to the Bolton plane. Its midpoint is known as point *S*. A measurement is made from point *S* to the nasion, and this distance is marked on the Bolton plane from point *S*.

A line is drawn from the center of the lips through the point just marked on the Bolton plane. This line may vary a few degrees up or down because it was started anteriorly from the lips. This line is accepted as the height of the occlusal plane even though it may not be the true location of the occlusal plane. However, the line is the midline between the basal bone of the maxillae and mandible. If denture teeth are in occlusion along this line, the force of mastication is applied

Fig. 1

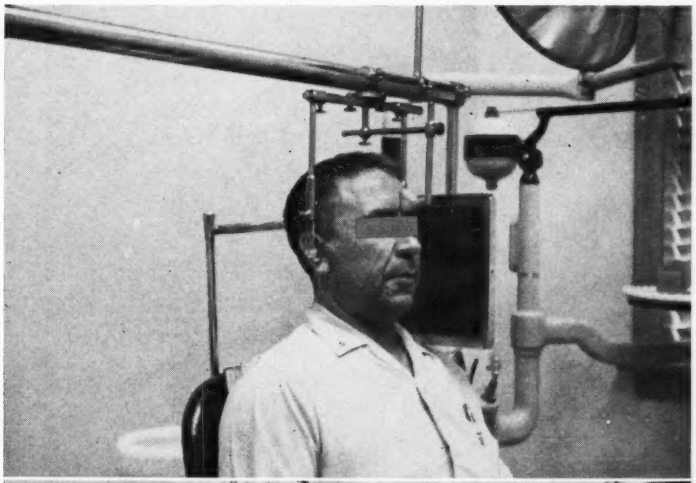

Fig. 2

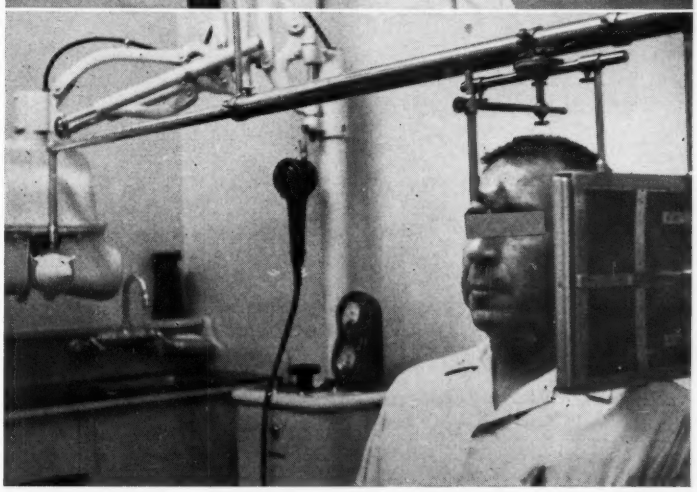

Fig. 1.—The patient is positioned in the cephalometer.
Fig. 2.—A lateral head roentgenogram is made with the head fixed in the cephalometer.

Fig. 3

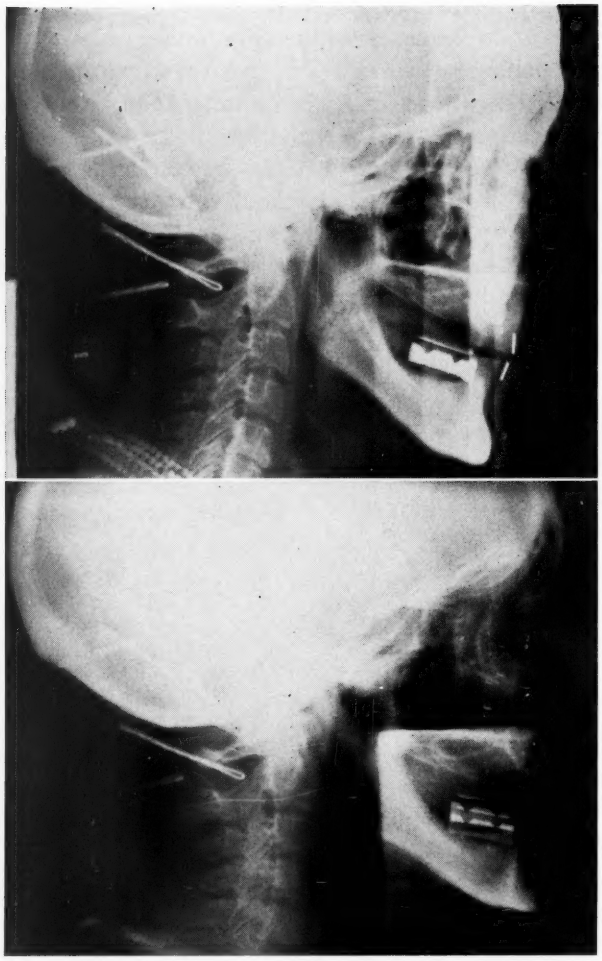

Fig. 4

Fig. 3.—A lateral head roentgenogram shows the markers in position on the occlusion rims. An upper occlusion rim was used instead of the complete upper denture for this illustration. The anterior markers are on the labial surfaces of the occlusion rims.

Fig. 4.—The roentgenogram shows the highest point of travel of the mandible during swallowing. The upper denture or occlusion rim has been removed.

equally to the mandible and the maxillae. Therefore, the dentures tend to seat themselves firmly in function.

A line is drawn parallelly to the facial plane through the tip of the anterior nasal spine. The labial surface of the maxillary central incisors normally is on and parallel to this line.

The distance between the nasion and the point of intersection of the mandibulofacial planes for both mandibular positions is measured and marked in millimeters on the tracing. The measurement of the second facial plane is less than that of the

Fig. 5

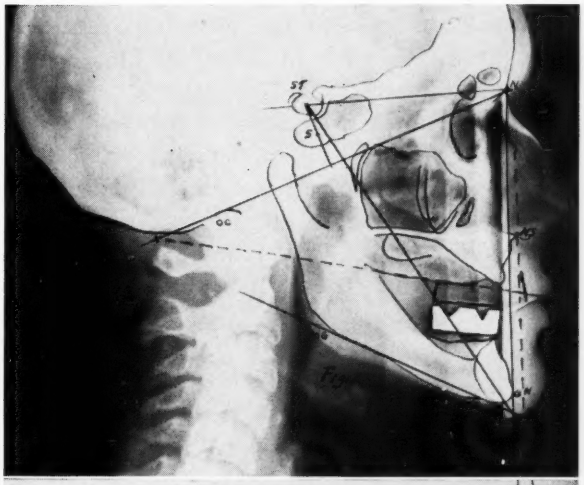

Fig. 6

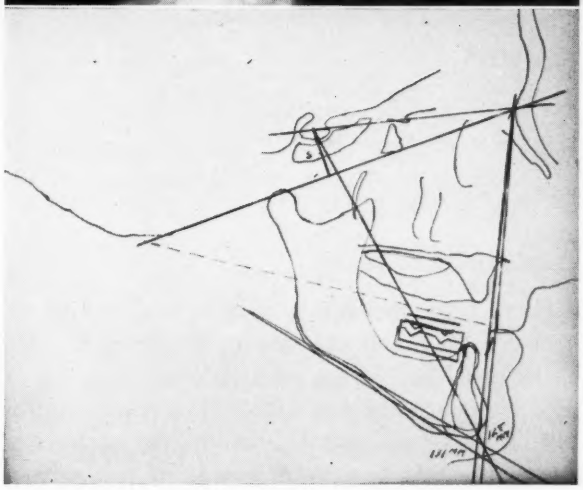

Fig. 5.—The planes to be drawn on tracing paper are located on the first roentgenogram.
Fig. 6.—The completed tracing shows the original position of the mandible, the degree of closure during swallowing, and the final position of the mandible to the highest point of travel. The distance between the original position and the swallowing position on this tracing is 3 mm.

first, because deglutition has moved the mandible past the distance of the slightly increased vertical dimension established before the roentgenograms were made. For example, if the measurement of the first facial plane is 128 mm. and that of the second is 125 mm., 3 mm. of wax is removed from the occlusion rim on the articulator. Most of the wax is removed from the posterior part of the rim, and a stop is left in the region of the central incisors. The stop is shortened 3 mm. (Fig. 7). Soft wax is added to the posterior part of the occlusion rim, and a new interocclusal record is made at the correct vertical dimension of occlusion.

FINAL IMPRESSIONS FOR RELINING

The final impressions are made at the corrected vertical dimension of occlusion. The upper impression is made in the upper immediate denture and the lower impression in the occlusion rim.

The upper impression is made first. Some of the temporary relining material is removed to eliminate undercuts, and the borders of the denture are reduced slightly. Nothing is removed from the palate or rugae area because this part of the denture must contact the palatal tissue when the impression is made. Two or three holes are made in the denture with a No. 8 round bur to serve as escapements for the excess impression material. The denture must fit snugly against the palate and rugae when the impression is made.

The lower tray borders, the lingual surface of the buccal flanges, and the buccal surface of the lingual flanges are relieved slightly. The crest of the alveolar groove is not relieved because it is used to guide the lower tray into its previously established vertical relation. A face-bow registration is made after both impressions are completed.

MOUNTING THE CASTS

The interocclusal relationship is verified, the impressions are removed from the mouth, and stone casts are poured. The upper denture and cast are mounted on an adjustable articulator with the teeth parallel to the base. The lower occlusal rim and cast are mounted by means of the interocclusal record.

ORIENTATION OF THE OCCLUSAL PLANE

If the wire marker on the tracing is parallel to the line drawn to represent the occlusal plane, no change in the orientation of the plane is necessary (Fig. 6). However, usually, the distal end of the wire is lower than the projected occlusal plane on the tracing. Therefore, the posterior end of both dentures must be raised so that the teeth in occlusion will parallel the desired occlusal plane.

Because the upper denture and lower occlusion rim were in contact when the roentgenograms were made, the wire marker was located below the plane of occlusion of the occlusion rim. Therefore, on the tracing, the wire appears lower than the projected occlusal plane. This is not important. For example, if the anterior part of the wire is 3 mm. lower and the posterior part is 6 mm. lower than the projected occlusal plane, the posterior end of the dentures must be raised 3 mm. to parallel the projected occlusal plane. Wax or modeling compound is attached to the anterior part of the lower occlusion rim to serve as a stop or fulcrum for the upper anterior teeth while the change in the distal end of the dentures is made.

Using the stated example, 3 mm. of wax is added to the lower occlusion rim on both sides in the location of the distal part of the wire. The upper denture is removed from the cast, and the impression material is removed. Enough acrylic resin is removed from the denture to permit the articulator pin to close when the denture is resting on the three stops provided on the occlusion rim. The upper denture is waxed to the cast. The posterior teeth on the upper denture are now 3 mm. higher than the occlusion rim and parallel to the projected occlusal plane.

CURING THE DENTURES

If heat-cured acrylic resin is used for relining, the occlusion rim is removed from the lower cast. Sufficient acrylic resin is removed from the lower immediate denture to permit closing the articulator pin while the teeth are in occlusion. When enough clearance has been provided, the upper and lower dentures are fastened in occlusion with sticky wax on the labial surfaces of the teeth, and the lower denture is waxed to its new cast. The sticky wax is removed, and the occlusion is checked for accuracy. Both dentures are ready for processing.

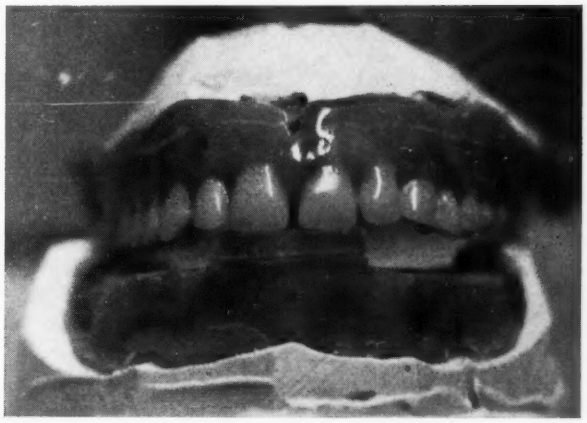

Fig. 7.—The height of the occlusion rim is reduced posteriorly. The mark on the anterior wax stop shows the amount of wax to be removed to establish the correct vertical relation of occlusion.

If cold-curing acrylic resin is used, the lower occlusion rim is not removed from the cast until the upper denture has been processed and cured. The cold-curing resin is mixed and placed in the upper denture and in the undercuts on the cast. The articulator is carefully closed so that the position of the dentures is not changed. If most of the palate has been removed, the articulator is inverted and held together by a strong rubber band. The resin is adapted to the palate with the finger. The inverted position is maintained until the resin cures either on the bench or in a pressure-curing unit.

When the upper denture-base material has cured, the lower occlusion rim is removed, and the lower denture is relieved until the articulator pin will close with the teeth in occlusion. The dentures are waxed together in occlusion with sticky wax, the resin is inserted in the lower denture, and the articulator is closed. Both dentures are removed and polished.

CORRECTION OF OCCLUSION

When the dentures are returned to the articulator after curing, the molars will contact first. The incisal guide pin may be open from 1 to 5 mm. because of changes occurring in processing. The occlusion may be corrected by selective

grinding at this time if desired. However, Applegate* suggests that the dentures be inserted, the patient recalled in 7 to 10 days, and the occlusion adjusted at that time. He feels that a certain amount of adjustment takes place in the mouth after insertion of dentures and that this change should occur before the occlusion is corrected.

SUMMARY

The pre-extraction appearance of the patient can be preserved with good immediate dentures. By properly servicing and correcting these dentures, appearance and function may be maintained for long periods of time with a minimum of destruction of supporting bone.

Cephalometrics has eliminated the guesswork in establishing the vertical dimension of occlusion since its use permits the muscles of mastication and deglutition to determine where the teeth should meet in function. An occlusal plane that distributes masticatory force equally to both the maxillae and the mandible can be established by the use of cephalometrics.

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CONDYLE POSITIONS IN UNIMPEDED JAW MOVEMENTS

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THIS ARTICLE is a preliminary report of a study of static condyle positions after unimpeded jaw movements. The objectives of the study were (1) to determine the relative positions of the condyles at rest position and during unimpeded passive and power closures, (2) to determine whether heavy manual pressure can displace a condyle posterior to the hinge axis position in a healthy joint, and (3) to determine whether the subject can retrude the mandible posteriorly to the hinge axis position. We designate this movement by the subject "autoretrusion."

This report is based on twenty-five groups of measurements on dental students or instructors in the New York University, College of Dentistry. All subjects had comfortable mouths and apparently well-functioning temporomandibular joints. Some subjects had missing teeth, poor restorations, or various malocclusions. Subjects were not acceptable unless the mouth was comfortable, the mandible could be manipulated without muscle interference, and the first or second lower molars were well supported by bone. The experimental appliance was attached to these teeth.

THE APPLIANCE

The condylar thesiograph† is an appliance that traces and records condylar positions. The thesiograph is essentially a lightweight hinge bow, but it differs from the conventional hinge bow in two respects: (1) the right and left sections are separate and (2) it is attached to the mandible by cementation to the buccal surfaces of a lower molar.

The thesiograph does not interfere with the occlusion of the subject so that it is possible to record locations of the condyles while the teeth are in actual contact in passive and power closures. This permits a greater range of movement for hinge axis determination since the appliance does not encroach upon the interocclusal distance.

The thesiograph is attached to the buccal surface of a lower molar by the use of a grid. The grids are cemented to the teeth with an acrylic resin cement. The grid supports two small tubes which receive two prongs of the connecting rod of the thesiograph (Fig. 1). The connecting rod comes out of the corner of the mouth and bends posteriorly (Fig. 2).

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**Associate Professor, Department of Fixed Partial Prosthesis.
†Designed by A. Zola.

A square tube that is fitted with a pinion gear is soldered to the connecting rod. A serrated square rod or rack slides within this tube and supports the pin recording device. The pin-holding device has a geared hinge. By adjusting the pinion gear and the geared hinge, the pins can be moved in any direction in a sagittal plane (Fig. 3).

EXPERIMENTAL METHOD

The hinge axis of the mandible was determined by pure manipulation (the word manipulation refers to the method of positioning the mandible). The patient was instructed to drop (not open) the jaw, and then the jaw was lifted or raised by the dentist while the action of the condylar pinpoint of the thesiograph was observed. The patient did not aid the closure of the jaw.

Fig. 1.—The tube attachment is cemented in position on the tooth.

When no closing muscle influence is present, a dentist can feel the condyles in their most posterior position without applying pressure. When the jaw movement is limited to one direction (closing), it is easier to adjust the condylar pin of the thesiograph. Some preliminary juggling of the jaw was done to help in attaining muscle relaxation and also to ascertain when complete relaxation was achieved.

The mandible was manipulated into the arc of hinge closure. The location of any existing hinge arc deflective occlusal contacts was noted. Interfering contacts in hinge closure were observed in varying degrees of severity in all subjects in the preliminary examination. Although this study was limited to subjects with "normal" temporomandibular joints, it is possible that one or more pathologic joint conditions were included in it.

Both sections of the thesiograph were mounted on the teeth (Fig. 4), and hinge axis points were located. The gears were locked with viscous wax, and the hinge axis point was recorded on the subject's skin. A base line from which all measurements were made was drawn from the hinge point to the outer canthus of the eye (Fig. 5).

Fig. 2.—The connecting rod is in position. The appliance does not interfere with the occlusion.

Physiologic Rest Position Record.—The mandible was brought to the physiologic rest position, and the points locating the condyles were recorded on the skin. No recording was made until several acceptable techniques for determining this mandibular position had been employed.

Passive Closure Record.—The passive closure positions of the condyles were recorded. The subject was instructed to bring the teeth lightly into contact. This mandibular position is unguided and represents the position of initial contact of the occlusal surfaces at the end of the unimpeded closure. This position also was repeated several times before recording the condylar positions.

Power Closure Record.—The mandible assumes the power closure position when maximal muscular contraction is made from the position of passive closure. The subject was instructed to clamp the teeth together as forcibly as possible for this record. The recording was made after waiting for the skin to come to rest.

Forced Retrusion Record.—To make a record of forced retrusion, force was applied to the patient's chin in a posterior direction with the heel of the hand while the head was supported in the occipital region by the other hand. This support was used to prevent skin movement. The amount of force was often sufficient to cause a response of pain from the subject.

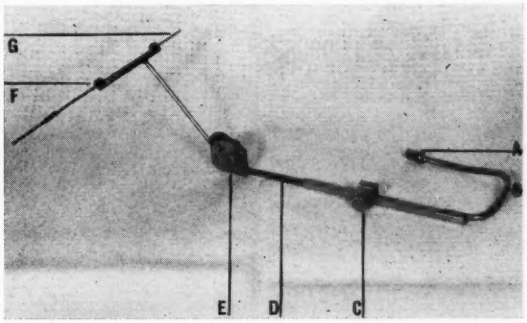

Fig. 3.—The right side section of the thesiograph: *(A)* the grid; *(B)* the connecting rod; *(C)* the pinion gear; *(D)* the rack; *(E)* the geared hinge; *(F)* the pin carriage; *(G)* the pin.

Autoretrusion Record.—To make a record of autoretrusion, the subject was asked to retrude the mandible as far as possible, and the locations of the condyles were marked.

The mandible was manipulated into the hinge axis position several times during the period in which these recordings were made and after the completion of the recordings. This procedure was followed to make certain that there was no shift of the appliance while the recordings were made and that skin or lip movements did not influence the markings.

A flashlight with a magnifying lens on one end of the head (Fig. 6) and a transparent plastic window lined with a millimeter graph on the other end of the head was used to measure the marks directly on the skin. The graph-lined window was placed directly over the base point line on the patient's face (Fig. 7). The base or hinge axis point was sighted under the junction of x, y coordinate axes, which were used to measure the recordings. The measurements were made in millimeters, and the figures were recorded on a chart (Table I).

SOURCES OF ERROR

Differences in pin location of 0.25 mm. were easily discernible with the use of the magnifier. During the early trials, unaccountable positions of the pin were

Fig. 4.—Both sections of the thesiograph are mounted on the teeth. Note the passive position of the lips. The connecting rod is rigid.

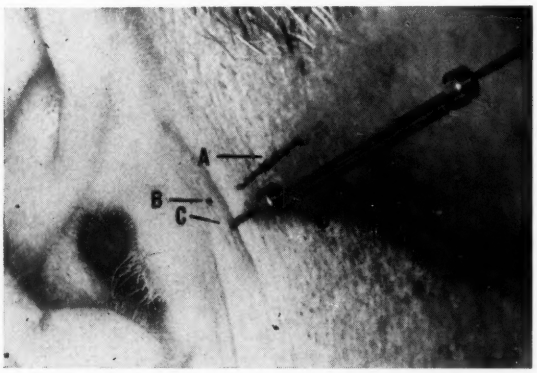

Fig. 5.—The skin markings show: *(A)* the axis-canthus line; *(B)* the hinge axis point; *(C)* the rest position point; *(D)* jeweled bearings for smooth, low tolerance action of the pin.

registered. These were caused by movement of the skin or of the instrument. One by one, all sources of error were eliminated. Finally, the procedure evolved into a continuous verification of constants. The jaw was manipulated, and the pin position checked with the previously marked hinge axis position or the base point before each new recording was made. In this way, any error resulting from mechanical variation or skin movement was discovered before the new registration was made.

DISCUSSION

The hinge axis point and the line to the outer canthus of eye from that point establish a constant base line which is repeatable in all subjects. The mandible was manipulated to determine the hinge axis position. It was necessary that the subject could permit the mandible to be manipulated into this position in order to qualify for this study. The mandible was held in exactly the same manner for each subject. The recording was made only when no resistance was felt by the dentist and when the thesiograph pin was adjusted so that it moved with pure rotation. All marks were made on the skin, which was a reliable marking surface if ample time was allowed for passivity after the movements were completed. All marks were made with the subject's head erect and supported at the occiput to prevent further skin movement.

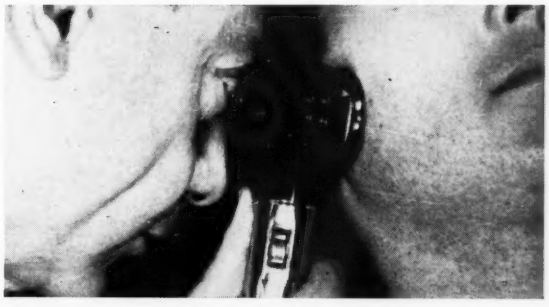

Fig. 6.—A magnifying flashlight is used to measure the marks directly on the skin.

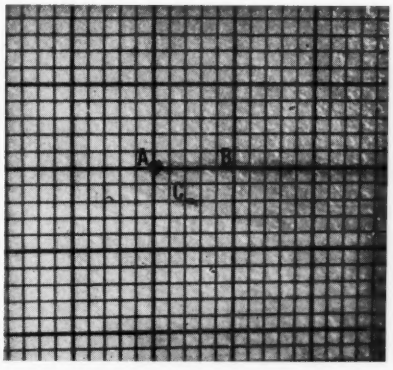

Fig. 7.—The millimeter graph window is seen through the magnifier: *(A)* the hinge axis point; *(B)* the axis-tragus line; *(C)* the rest position recorded as 2.25-2.

TABLE I. LOCATION OF TEST POSITIONS AS COMPARED WITH THE HINGE AXIS POSITION (IN MILLIMETERS)*

CASE	REST POSITION		PASSIVE CLOSURE		POWER CLOSURE		FORCED RETRUSION		AUTO-RETRUSION	
	R	L	R	L	R	L	R	L	R	L
1		−1.00								
2		−0.50								
3	0.50 −0.50	0.50 −1.00								
4	0.50 −0.50		0.50 −0.50	−0.50 −1.00	0.50 −0.50	−0.50 −1.00	0.50 −0.50	−0.50 −1.00	0.50 −0.50	−0.50 −1.00
5		−0.50 −1.00		−0.50 −1.00						
6	0.75 −1.50	0.25 −0.50								
7	−2.50	−1.00	−1.00	−2.00						
8	−1.50	−1.25 −1.50		−1.00 −0.50		−0.50				
9	0.50 −2.50	0.25 −2.50				−0.50 −0.50				
10										
11	−1.50	−0.50 −1.50								
12	−1.00 −1.50	−1.75								
13	0.25 −0.25									
14	0.25 −0.25					1.00				
15	0.25 −2.00	−1.50								
16	0.25 −0.25	−0.50 −2.50	0.25 −0.25	0.50	0.25 −0.25	−0.50				
17	−3.25	−0.50	−1.25	−0.50 0.50		−0.50 0.50				
18	−0.50	0.25 −1.25	−0.25 −0.50	0.25 −1.00						
19										

*Blank spaces indicate no deviation from the hinge axis position.

TABLE I (CONT'D)

20	0.25 −1.75	−0.50 −1.50								
21	0.25	−0.50 −1.00								
22			0.50 0.50		0.50 0.50					
23	1.50 −1.50	−1.00 −2.00	1.00	−1.00 −2.00	0.25 0.75	−1.00 −1.25				
24										
25	0.25 −1.00	−1.00 −1.00		−0.50 −0.50						

The recordings used for this report represent terminal, static positions of the condyles. They represent terminal positions since they were recorded at the end of the movements. They are repeatable. All records were made in a single plane, but a set of readings along the x axis gave an idea of the amount and direction of mandibular deviation.

Interfering contacts in arc closure were always observed in varying degrees of severity in the preliminary examination of the subjects. Although this study was limited to "normal" temporomandibular joints, it is possible that one or more impaired joints were observed.

ANALYSIS

The analysis of the findings is divided into four parts (Table II): (1) the relationship of the rest position to the hinge position, (2) the relationship of the passive closure position to the power closure position, (3) the relationship of the power closure position to the hinge position, and (4) the relationship of the retrusion position to the hinge position.

Relationship of the Rest Position to the Hinge Axis Position.—Sixteen per cent of the rest position registrations were in the exact hinge axis position, while 84 per cent were within 3 mm. of the hinge position in various directions except dorsally or superiorly. Many rest position registrations were asymmetrically located on the right or left side. There was no predictable relationship of the rest position to the hinge axis position. This finding agrees with those of Posselt[1] and Nevakari.[2]

Relationship of Passive Position to the Power Closure Position.—The patient was instructed to bring the teeth together without pressure when making a passive closure. At this point, the teeth make a number of occlusal contacts. If more contacts are made when power closure is effected, the mandible will be deflected. The difference in the number of actual contacts made in passive closure as compared to those made in power closure determines, to some degree, the deflection from

TABLE II. RELATIONSHIP OF THE TEST POSITIONS TO THE HINGE AXIS POSITION

RESULT	REST POSITION	PASSIVE CLOSURE	POWER CLOSURE	FORCED RETRUSION	AUTO-RETRUSION
Test position was identical with hinge position	4	15	17	24	24
Test position deviated from hinge position	21	10	8	1	1

the passive to the power closure position. If there is no coincidence of the passive and power closure positions, it is a result of true deflection of the mandible.

Sixty-four per cent of the passive and power closure positions were coincident. Of these, 52 per cent were on the hinge axis position, while 12 per cent were off the hinge axis position. Twenty-eight per cent were not coincident and were not in the hinge axis position.

Any deflective action would be destructive because masticatory pressures would be applied to a fraction of the total available contacts. Therefore, it is desirable to have passive and power closure positions coincident and in hinge axis position.

Relationship of Power Closure Position to Hinge Axis Position.—The relationship of the power closure to the hinge axis position was the main objective of the study. Sixty-eight per cent of the power closure recordings were in the hinge axis position.

An ideal condition is present when the power closure position is coincident with the hinge axis closure position. This coincidence of positions exists in the presence of mild interfering contacts which are somewhere along the arc of closure.

The terms deflective occlusal contacts and premature contacts should be differentiated. Premature contacts are initial contacts of usually one maxillary and one mandibular tooth when the lower jaw is manipulated and raised in hinge arc closure. This closure is extremely useful in obtaining the hinge axis and for achieving simultaneous tooth contact in restorative work.[3] However, it is an artificial closure and has no relationship to unimpeded closure or to impeded closure through a bolus of food.

Most of our subjects had some form of premature contact in the hinge arc of closure, yet many of these same subjects fell into the category of coincident positions. These premature contacts had no real influence on the final closure position. The high percentage of coincident recordings indicates that the coincidence of the power closure position and the hinge axis position is highly desirable.

Relationship of Retrusion to Hinge Axis Position.—There was only one incident of posterior movement of the condyles relative to the base point or hinge axis position in autoretrusion and manually induced forced retrusion.

An illusion is created subjectively when an individual tries to retrude the jaw. There is a distinct feeling of posterior movement of the mandibular teeth as they

slide against the upper teeth and a feeling of constraint in the temporomandibular joint. Actually, what appears to be posterior movement is the sliding of the inclined planes of the teeth of both jaws as the jaws move toward and away from each other.

Arstad[4] described the wear facets present on the inclines of the cusps that resist retrusive forces. He measured the angulations of these facets as related to the hinge arc of closure and showed that they are parallel or tangential to the hinge arc of closure.

Actually, what appears to be posterior movement is an opening of the mandible on the hinge arc. The condyles remain in their most retruded position and simply rotate. Our records on forced and autoretrusion indicate that this could be the logical explanation for the attitude that the mandible can be retruded beyond the hinge axis position.

CONCLUSIONS

1. The rest position of the mandible has no predictable relationship to the hinge axis position. Only 16 per cent of the rest position records were on the hinge position, while the other 84 per cent were haphazardly located in relation to it.

2. It is desirable for passive and power closure positions to be coincident and that they both be in the hinge axis position.

3. Not all premature contacts are deflective in Nature, and consequently not all premature contacts are destructive.

4. Both manual and autoretrusion of the mandible resulted in identical hinge axis positions in 24 out of 25 subjects. Both methods were devoid of closure muscle influence.

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REMOVABLE PARTIAL DENTURES

EVALUATING ORAL STRUCTURES FOR REMOVABLE PARTIAL DENTURES

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REMOVABLE PARTIAL DENTURE SERVICE provided by a person with less training than the dentist is hazardous to the dental well-being of patients. Every type of dental skill is ultimately called into play to handle the wide variety of conditions created as a result of partially edentulous situations. These needs may include endodontic, periodontic, and orthodontic treatment, surgical preparation of the patient, and every phase of operative and restorative service. Time, ingenuity, and diversified skill are required of well-trained dentists to adequately prepare the mouth for removable partial denture service because of the difficult situations which usually follow the migration and disarrangement of the teeth.

EVALUATING ORAL STRUCTURES

One of the more exacting prerequisites to the planning of a removable partial denture is an evaluation of the remaining oral structures. These structures may have deteriorated if much time has elapsed before prosthodontic service is sought. The degree of damage varies greatly.

The judgment of one trained only for dental laboratory service will be most conspicuously inadequate in the area of diagnosis, prognosis, analysis, and evaluation. Such determinations can be made intelligently only on a firm basis of proper training in the basic sciences. The characteristics of a normal oral structure must be known to be able to estimate the degree of abnormality which may be present. This one requisite infers no less than a background knowledge of anatomy, physiology, histology, and pathology.

The one outstanding evidence of progressive advancement in removable partial denture prosthodontics is the general acceptance of the biologic concept rather than that of merely the mechanical filling of a void in the broken dental arch. The type of removable partial denture should not be determined just on the

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basis of the location of the edentulous space or by which teeth are missing in the dental arch. Something more must be considered than merely what is determined from examining and surveying a dental cast. At times, without guidance or adequate instruction, the dental laboratory technician is commanded to make "something" to fill the space on a cast. This type of prosthetic service by a dentist is inadequate, and it should be strongly condemned.

CHOICE OF THE PARTIAL DENTURE

The choice of a partial prosthesis should be made so that there is the least chance of damaging the supporting structures. Therefore, the induced work load must not exceed the tolerance of these tissues. It thus becomes urgent that there be a dependable way of estimating the status of these structures.

ORIGIN OF PROSTHESIS SUPPORT

When a restoration is called tooth borne or mucosa supported, what idea does one get of its support? Actually, each prosthesis is really *bone* supported. The periodontal membrane of the abutment teeth in the one instance, or the tissue covering over the ridge in the other, is merely the fibrous connective tissue by which the work load is conveyed to the supporting bone.

The prosthesis which rests on tooth abutments for total transfer of the occlusal load causes the principal fibers of the highly specialized periodontal membrane to stretch. The work stress is passed from the surface of the suspended root to the alveolar wall of bone, with alteration of the fibers from a relaxed to a tensed and lengthened state.

When a denture base presses against the underlying mucosal pad, these structures momentarily become compact or displaced, and the work load is passed on to the bone under the denture base. The two systems of transfer are utterly different, but the result in either instance is that the bone becomes the supporting structure. All fixed or removable dental restorations are, in reality, bone borne or bone supported. Therefore, an analysis of the existing condition of the alveolar process is the most important diagnostic criterion to be studied in preparation for partial denture service.

EVALUATION OF BONE

There are two conditions about which dentists should be further informed to estimate the dependability of the alveolar process as a support: (1) to what degree does the patient show an ability to maintain the alveolar process where it is known to have been receiving more than normal stress loads and (2) how much cervical bone has been lost around the teeth in general and, particularly, around prospective abutment teeth?

If the bone is being maintained normally, the prospects for good restorative results are bright. The patient is metabolically normal so far as the nurturing of the bony process is concerned. Bone elements are being deposited at least as rapidly as they are being used up.

Typical key areas for detecting evidence of adequate bone replenishment are (1) those zones where the bone has supported abutment teeth, (2) the bone supporting teeth adjacent to a posterior edentulous area, and (3) the bone adjacent to a posterior tooth that is tipped mesially out of its normal vertical position. In each of these situations, the bone supporting the tooth will be subjected to serious overload. If the patient has been able to maintain a fairly normal bone level about the teeth in these index areas, one may assume that the metabolic function is normal so far as bone maintenance is concerned. In mouths of this type, the supporting bone can assume an added prosthetic load without the danger of breakdown. Teeth which bound the edentulous space, if otherwise capable, can be expected to assume abutment service successfully.

On the other hand, if there has been a process of bone depletion or disorganization in places of known overload, bone formation probably will not keep pace with the process of bone depletion, and an area of destruction results. Very simply, the tolerance limit of the alveolar process has been exceeded. Thus, when a condition of normal bone exists together with favorable abutment root form and length, a removable unilateral partial denture might be used to replace each lower first molar. Here, the strong boundary teeth can assume the total load of both lateral and vertical stress forces.

Yet, in an instance of unfavorable bone support, a bilateral removable prosthesis is urgently needed for the same spaces (lower first molars missing). Lack of adequate support is evidenced by (1) previous loss of bone at the cervical level of the tooth, (2) evidence of the inability of a patient to maintain bone normally (low tolerance), (3) excess mobility of boundary teeth, and (4) short, excessively tapered, or very thin-rooted teeth. Any one or a combination of these unfavorable conditions requires cross-arch splinting of the weak abutment teeth. The mechanical assistance of counter leverage is utilized to compensate for the disadvantage of existing physical disability. Thus, the bilateral prosthesis may succeed where the two unilateral ones would have failed.

Vertical loading parallel to the abutment root axis effects a transfer of the occlusal stress by the stretch or tension mechanism. This is a relatively safe procedure because it does not inhibit circulation and there is not much chance of overloading, since the biting forces are limited by involuntary proprioceptive control. It is the laterally directed forces which may destroy tooth support. Under this stress, the abutment tooth is tilted in its alveolus, and the periodontal membrane becomes pinched. This ultimately may cause change or even loss of the adjacent bone (pocket formation).

The dentist is capable of effectively evaluating the status of the supporting structures by virtue of the diagnostic means at his command. He can then prepare the remaining teeth to assume the new work load to be placed upon them. He may unite two or more weakened teeth to offset unfavorable physical characteristics and thus produce a multiple abutment which can more safely assume extra work loads.

The dentist is capable of advantageously directing the designing of the removable prosthesis so as to most effectively reduce the induced stress load. Hence, a

removable partial prosthesis that is properly planned may serve to preserve oral structures. The technical aspects of the fabrication of a partial denture by the dental laboratory technician are only a part of the total service. A proper balance of these two essential contributions to the prosthetic service of the public must be maintained. A skilled, properly trained dental laboratory technician can fabricate the restoration, but the prescription must be left to the dentist.

RESPONSIBILITY OF THE DENTIST

The dentist must be sure of his diagnosis by basing it on a careful and complete examination. The capability of the bone to support the contemplated work load must be assessed, and then the mouth must be adequately prepared to accept only that amount of functional load which the oral structures seem to be capable of bearing. Finally, a denture design which seems to be most likely to meet the situation must be prescribed. The dentist is responsible for this planning, and failures should not be blamed on the laboratory technician when he has only carried out orders.

There will be some denture failures. However, it often is not the partial denture but the foundation that fails, because the patient can no longer maintain the bone. He may develop a systemic problem which occurs after the service is completed. Therefore, the patient who presents a borderline situation must be told that as a result of his condition, it may be unavoidable to prevent the loss of the remaining teeth.

SUMMARY

The welfare of the public will not be best served by the delegation of removable partial denture service to inadequately trained personnel. The dentist must concentrate on finding proper ways of simplifying partial denture procedures without endangering the health of the oral structures. In this way, more patients may be treated at a reduced cost. If dentists do not assume the responsibility of making this service available, others less qualified will.

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PRETREATMENT EVALUATION OF PARTIALLY EDENTULOUS PATIENTS

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TECHNICAL FAILURES resulting from incorrect design, poor fabrication, or structural weakness of restorations are not the most serious causes of failure in treating partially edentulous patients. Of much greater concern are those failures which result from inadequate original diagnosis.

TREATMENT PLANNING

The dentist must fortify himself with all the information that roentgenograms can supply in all cases in which restoration of occlusal surfaces is contemplated (Fig. 1). A minimal survey includes fourteen periapical and two bite-wing films. Additional views are often necessary. Temporomandibular joint dysfunction should be investigated roentgenographically for abnormalities of structure. Roentgenograms are excellent for demonstrating to a skeptical patient the existence of caries, extensive periodontal involvement, impacted teeth, foreign bodies, or other abnormalities.

There is no substitute for mounted diagnostic casts in demonstrating occlusal interferences and mechanical difficulties of placing artificial teeth or of attaining retention of the proposed restoration (Fig. 2).

MAJOR CAUSES OF LOSS OF TEETH

The major causes of loss of teeth are dental caries and periodontoclasia. Consideration of both of these common dental diseases figures prominently in the plans for substitution of teeth. There is no way to predict the course of the future except as it is based upon the experiences of the past.

Caries.—Special problems of inquiry are posed when the major cause of tooth loss has been caries. No remaining teeth should escape exhaustive vitality tests. All teeth with large restorations of a questionable nature, especially those which will serve as abutments, should be explored by removing all filling and base material. Teeth which fail to respond to vitality tests or which show pulpal involvement are considered for removal or root canal therapy. Endodontic therapy is particularly indicated for such potential abutment teeth.[1]

The opinions and assertions contained in this article are the private ones of the author and are not to be construed as official or reflecting the views of the United States Army.

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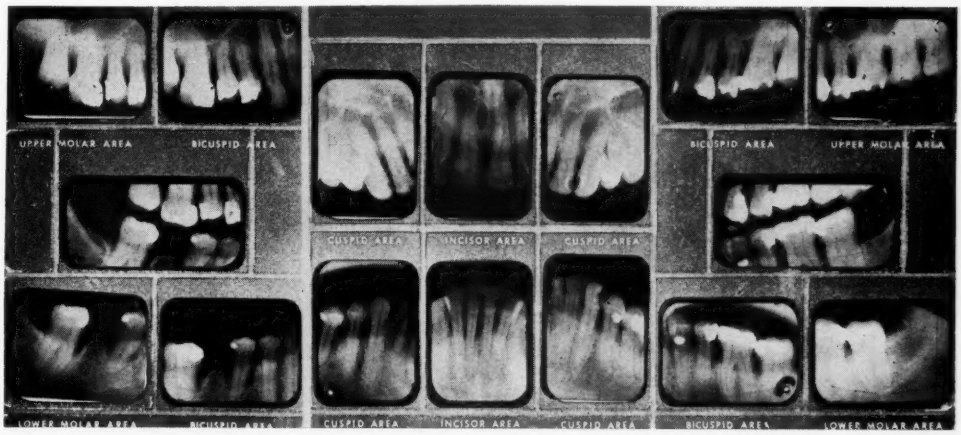


Fig. 1.—Roentgenograms of a 48-year-old woman who gave a history of intermittent periodontal care for 7 years and admitted to poor cooperation in home care. The patient was highly excitable and apprehensive of dental treatment. This patient had an unfavorable prognosis for either fixed or removable partial dentures.

A complete veneer crown is always the abutment of choice for either fixed or removable dentures in caries-susceptible mouths (Fig. 3). Class I, II, and V metallic restorations are acceptable for abutment teeth of removable partial dentures in relatively caries-immune mouths. Such patients frequently have etched and discolored enamel surfaces or occlusal surface faults with no evidence of active caries.

Gold is the material of choice for abutment restorations. However, amalgam can be adequate, and it enables the dentist to apply protective measures within the financial ability of the patient.

Periodontal Disease.—The wisest approach to predicting the eventual response to therapy and the probable life of the proposed restoration is first to attempt what Glickman terms an "over-all prognosis."[2] The dentist must be able to distinguish between generalized, destructive periodontal disease and a periodontium that is sound over-all but has localized involvement of an individual tooth or group of teeth. After this initial appraisal, determination of the prognosis of individual teeth is possible.

Chronic periodontosis, particularly when associated with a known systemic disease, offers the greatest possible hazard to substitution of lost members. In general, an extensive partial denture prosthesis is contraindicated in a mouth with advanced alveolar bone loss where no local pathogenic factors are evident or in the presence of a known but poorly managed metabolic disease or dysfunction (Fig. 1).

The over-all prognosis is equally favorable for a partial denture for other patients. In these instances, the general bone height is approximately at the level expected for the age of the individual. Local causative factors are easily identified where isolated areas of destruction have occurred, because there is evidence of the efforts of the tissue to repair the damage locally. Failure to display advanced general bone loss in marked chronic inflammation is another favorable sign. Undeniably

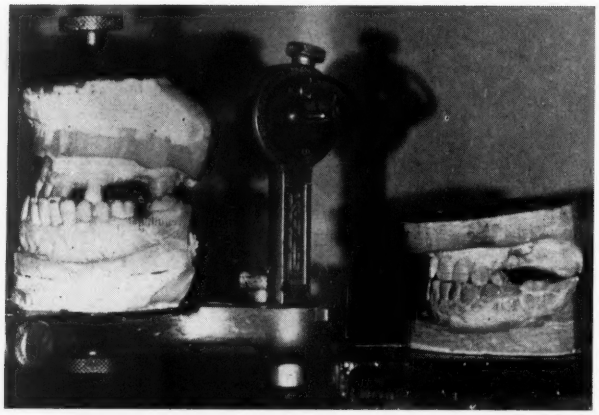


Fig. 2.—Diagnostic casts mounted on an adjustable articulator offer obvious advantages over those which must be related loosely in the hand.

Fig. 3.—A 26-year-old man had extensive carious involvement of the remaining upper teeth. The second molars and canines served as abutments for a removable partial denture and are protected by full veneer crowns.

excellent general health and a hardy physique, coupled with an adaptable personality, add appreciably to a favorable prognosis.

The patient whose over-all prognosis could be labeled questionable and whose circumstance demands more thorough evaluation lies between these two extremes. Alveolar bone height is at a general level below that considered normal for the age group. Such destruction often has taken place without the classic signs of extensive inflammation. Radiant good health is absent, and complaints of poorly defined ills are frequent. Many of these patients give evidence of mental stress; others are unnecessarily obese or emaciated. Some patients display a thorough disregard for proper oral hygiene and show little inclination to learn new habits.

Within the framework of this general classification, such signs as tooth mobility, periodontal pockets, bifurcation or trifurcation involvement, unfavorable root anatomy, and apical disease must be weighed carefully. The presence of one or several of such local signs has entirely different significance in a favorable mouth as against one labeled unfavorable or questionable.

In addition to good periodontal treatment, several mechanical aids can change the qualification of abutment teeth from unusable to usable. For example, a tooth with a single, short, tapering root is more acceptable as an abutment if it is joined to an adjacent tooth (Fig. 4). The same is true of a tooth with slight mobility or a modest infrabony pocket.

Some of the circumstances under which potential abutment teeth can be considered adequate in the presence of periodontal involvement are shown in Table I. The term rigid fixation is borrowed from Cohn,[3] who advises multiple abutments joined by crowns for mutual support in both the mesiodistal and buccolingual directions. Although Cohn states that "the fixed appliance is an ideal restoration," there are instances in which its use is awkward. Weakened, isolated distal molar abutments are an example. If multiple abutments are utilized anterior to the edentulous space, a disproportionate share of the occlusal load will be borne by the single distal abutment.[4] Lateral forces will be especially harmful because of the lack of buccolingual support.

TABLE I. FACTORS IN PROGNOSIS

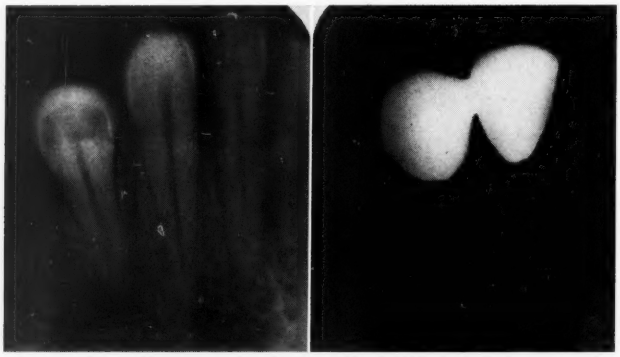
ABUTMENT TOOTH CHARACTERISTIC	OVER-ALL PROGNOSIS	
	FAVORABLE	QUESTIONABLE
Mobility		
Slight	Rigid fixation	Rigid fixation
Moderate	Rigid fixation	Unusable
Severe	Unusable	Unusable
Location in relation to free end edentulous area		
Isolated	Rigid fixation (with the most mesial teeth supplied by a fixed appliance)	Unusable
Approximating tooth	Usable	Splint
Location in relation to edentulous area (not free end)		
Isolated		
Multirooted	Usable	Rigid fixation
Single root	Rigid fixation	Unusable
Approximating tooth		
Multirooted	Usable	Usable
Single root	Usable	Rigid fixation
Periodontal pocket		
Relative	Usable	Usable
Absolute		
Gingival	Usable	Usable
Infrabony	Usable (if not so severe as to incite extensive mobility or preclude pocket elimination)	Unusable
Root anatomy		
Normal	Usable	Usable
Short and tapering	Rigid fixation	Unusable

FUNCTIONAL RELATIONSHIPS

The dentist must investigate thoroughly the many functional relationships of the stomatognathic system. Keen clinical perception based upon a sound knowledge of physiology is the single most valuable diagnostic aid.

Opening and Closing Movements.—Proceeding in an orderly fashion, the dentist should first observe the opening and closing movements of the lower jaw. The opening component should not be extreme, merely a comfortably wide extension. The patient should then be instructed to close upon the back teeth with modest force while the lips are retracted. Sicher[5] calls this terminal position with maximum contact between upper and lower teeth the median occlusal position. It is also referred to as centric occlusion.

In the normal individual, opening and closing movements are performed easily, painlessly, and with certitude. There will be little deviation of the mandible to one



A. *B.*

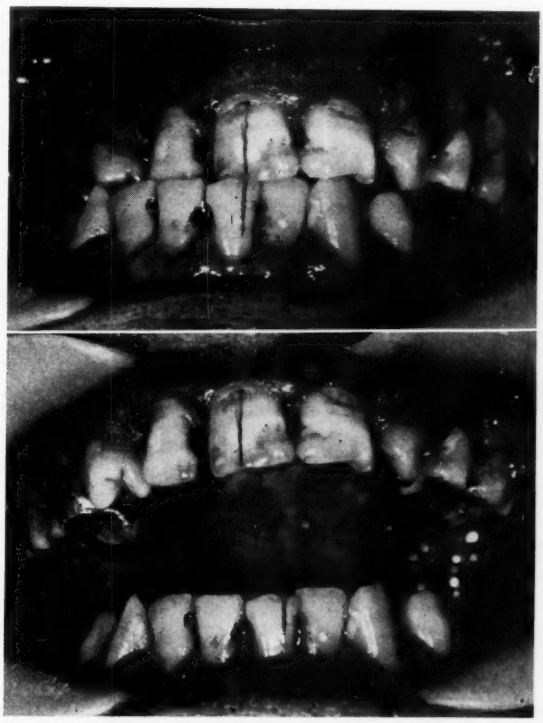
Fig. 4.—A 35-year-old man with a favorable prognosis. Earlier tooth loss was due to caries. *A*, The lower first premolar has a short, tapered root. *B*, The tooth was used as an abutment for a removable lower partial denture after being joined to the adjacent cuspid.

side of a vertical line, and the sound of the teeth as they meet will be one of simultaneous contact. If there are decided deviations to the right or left in either the opening or closing movements, the immediate cause may be sought in the temporomandibular joints. However, the ultimate cause is most often found in the centric occlusal position.

Deviation on Opening.—Deviation on opening is often the result of involuntary "splinting" of one joint in order to avoid pain (Fig. 5). Palpation of the joints through the external auditory meatuses elicits increased pain symptoms on the affected side and permits the dentist to note undue friction during movement. Local symptoms of pain, clicking, tenderness over the joints, and muscular pain may have more serious implications. However, these symptoms most frequently are indicative of degenerative joint disease.[6] Of the several etiologic factors of degenerative arthritis, the most common is trauma resulting from a centric occlusion that does not coincide with centric relation.

Deviation on Closing.—Deviation of the mandible on closing is not always associated with joint disease. If, because of migration, supraeruption, faulty restorative dental procedures, or other cause, a tooth contacts prematurely in centric occlusion, a new mandibular position will be sought. After only a few closures, this new position becomes fixed enough to permit immediate closure without gliding of the occlusal surfaces over one another. This is possible because of the innate necessity of an occlusal position involving maximal contact. The neuromuscular

A.



B.

Fig. 5.—A 26-year-old man had no complaint except that of insufficient remaining natural teeth. He had a marked asymmetry of the lower half of the face. No history of trauma could be elicited, and roentgenograms disclosed no bone abnormalities. Electrical stimulation of the musculature produced bilateral movement, but the patient could not perform any movement which would cause the left condyle to move forward in the fossa. *A*, Centric occlusion. *B*, The mandible deviated to the left during an opening movement.

reflex which makes the return to such a position possible has been compared to the motion of bringing the index finger from an outstretched arm position into unerring contact with the nose even though blindfolded.

A closing motion which is oblique in direction between the open position and centric occlusion is performed at the expense of bilateral muscular harmony. Also, centric occlusion will not be coincident with centric relation. To test this latter

thesis, the patient is positioned comfortably erect, the back supported, and the head held upright with the eyes level. The whole attitude should be one of relaxation. If the patient is apprehensive, premedication with muscular relaxants or hypnotic drugs may be of value.[7] The exercise of widely opening and closing the mouth many times assists by tiring the musculature.

An intelligent, cooperative patient benefits from a brief explanation of the procedure and the position. Patient cooperation is particularly necessary to permit retraction of the lips for observation. Most patients have a conditioned reflex which causes them to part the lips and teeth when the dentist's hands approach the mouth. After a few trials, a patient can relax the lower jaw in a position of modest opening. The opening should promote movement in the temporomandibular joints only between the condyles and the meniscuses. An opening which permits a forward glide of the meniscuses along the eminences is too wide and should not be accepted. From this open position, the patient should be able to move the mandible directly toward a closed position without deviation and stop the movement at the first tooth contact. The removal of these deflective occlusal contacts to permit a simple, bilaterally harmonious closure to centric occlusion when the jaw is in centric relation is the goal. Selective grinding may prove sufficient for simple corrections; however, in extreme instances, reconstruction of the occlusal anatomy of the teeth in one or both dental arches may be necessary.

Rest Position.—Rest position is often used to establish the proper vertical relation of occlusion for edentulous or partially edentulous patients. Moyers[8] describes rest position as a postural position and couches his definition in terms which relate to the neuromuscular mechanism.

A measurement is made between reference points on the nose and chin while the jaw assumes the rest position. A second measurement between these same reference points when the jaws are in the position of centric occlusion enables the dentist to judge the amount of interocclusal distance. The range of the normal interocclusal distance is considerable, and measurements ranging up to 5 mm. can be considered normal.

A deep vertical overlap of the anterior teeth is not necessarily indicative of a reduced vertical dimension of occlusion even though the lower incisal edges impinge upon the upper lingual gingivae. Collett and Lasoff[9] speak of deep vertical overlapping of the anterior teeth of both endogenous and exogenous origin in which a lessened vertical dimension of occlusion was not a factor.

An obvious lack of adequate posterior occlusal support may be evidence of a loss of the vertical dimension of occlusion. The resulting damage to the relationship of the anterior teeth is easily visualized. The lower anterior teeth contact the inclined plane of the upper lingual surfaces and may cause a posterior displacement of the mandible. Labial migration of the upper anterior teeth is also a common result.

Most of the positions described can be transferred to an adjustable articulator. This procedure is essential at the planning stage when occlusal reconstruction is considered. The opportunity to observe deflective occlusal contacts, interferences in lateral occlusal positions, and corrections needed in the vertical relation of occlusion is increased in this abstract fashion.

SUMMARY

Many aids to good diagnosis are available to the dentist and should be used. An accurate diagnosis is necessary if the amount of treatment time is to be estimated accurately.

An exhaustive investigation must be made of the extent of damage by caries and periodontoclasia in the pretreatment planning for partially edentulous patients. An appraisal must be made of the degree of response generated in the tissues toward repair of the damage done by these diseases.

Interruptions to proper functional movements must be appraised and any indication of permanent, irreparable damage to good function noted. Plans must be made for the removal of inhibitions to proper function and for protection of the remaining teeth against further attack by disease.

The fixed or removable partial denture in this method of treatment becomes merely one of the means of good therapy rather than an end in itself.

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CONTINUOUS COVERAGE LOWER REMOVABLE PARTIAL DENTURE

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ALL AVAILABLE TISSUE once was covered with mandibular vulcanite removable partial dentures, including the tissue lingual to the anterior teeth. However, with the development of the casting process, the lingual bar denture with attached clasps came into prominence. While the deficiencies of vulcanite were sufficient to encourage the change, the trend has introduced some new difficulties.

The most valuable lower partial denture is the one that has the longest life expectancy and best preserves the remaining natural teeth. Correctly constructed removable partial dentures should be expected to function for the greater part of an active lifetime.[1]

MANDIBULAR RESORPTION

In contrast to that of the maxillae, mandibular resorption affects the entire denture-bearing area. The lower jaw is in a state of continuous change from the time of the extraction of teeth on throughout life. The ridges, composed often of scar tissue, may conceal sharp edges and spicules of the alveolar process. In addition, the mucosa may cover unevenly resorbed bone some of which is not discernible until settling of the denture has occurred. Surgical operation later may not remove the jagged imperfections but create more. Damaged and painful nerve endings which do not heal completely after the removal of teeth may remain permanently sensitive to the pressures of mastication.

LINGUAL BAR

The sole purpose of a lingual bar is to unite the denture bases and to carry clasps. The lingual bar must be made of a relatively heavy gauge material to withstand stress. Arms or rests placed against the anterior teeth may be added to the lingual bar to counterbalance upward movement of the denture bases. These additions may act as an irritant and may cause the anterior teeth to move out of position.

The orthodox lingual bar does not utilize all available denture foundation tissue. The lingual bar may not be comfortable, therefore some patients often prefer the continuous coverage type of lower removable partial denture.

MAGNIFYING SENSATION

The cooperation of the patient may represent the difference between success or failure. The nerves of the tongue have a magnifying sensation factor of 3:1 to

4:1. Thus, foreign objects feel larger than they are. The superficial nerves of the eye have a similar and sharper response.

An object ⅛ inch in diameter feels like an object ⅜ to ½ inch in diameter to the exploring tongue. While this magnification is of some importance in the adaptation to the upper denture, it becomes of critical consequence in the lower denture because the tongue continually contacts the denture. The new lingual bar will feel as thick as a lead pencil. A sensation of pain may decide the issue.

CONTINUOUS COVERAGE

The external surfaces of the denture hug the contours of the mandible with a continuous coverage denture. The tongue does not have new reference points to measure and compare as with a lingual bar. The total thickness of a plastic lingual flange is less than that of a bar when the space between the bar and the mucosa is included. The plastic lingual flange with a thin stainless steel transverse reinforcing wire embedded in it provides a surface that is smooth and nonirritating to the tongue (Fig. 1). The combination of hard plastic and tough metal withstands the forces of mastication and the twisting pressures applied when the denture is removed from the mouth.

NEW MATERIALS

The advantages of the old type of continuous coverage dentures may be realized again by using the new materials. The deficiencies of vulcanite no longer exist. The new denture plastics with their hardness, dimensional stability, natural colors, and tissue blends, plus the use of stainless steel reinforcements, provide a fresh approach to an old problem.

SUPPORT AFFORDED BY THE LINGUAL FLANGE

The connecting parts of plastic reinforced with metal support the denture by covering the tissue lingual to the anterior teeth. This additional flange may double the foundation coverage and reduce much of the pressure formerly placed on the overworked denture bases.

The clasps may be made of gold or chrome-cobalt. Gold is desirable because of its resiliency and long life. The clasps may be wrought or cast and soldered or welded to the reinforcement wire. The hardness of the transverse wire, usually 12 gauge, and the elasticity of the gold in the clasps result in a durable combination (Fig. 2).

SUPPORTING ARMS

Extra supporting arms resting against the anterior teeth to resist upward movement of the denture bases are not needed. The entire upper margin of the lingual flange acts as an indirect retainer. Instead of being placed against the relatively unyielding surface of the tooth enamel, the retainer is placed against the tough and resilient mucosal tissue, which is well able to resist the sudden movements of the denture during mastication.

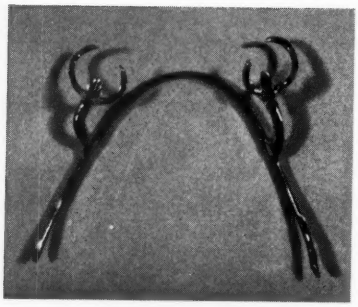

Fig. 1.—The wire frame for a continuous coverage lower removable partial denture may be of wrought or cast metal and is usually of 12 gauge thickness. The clasps are attached to the wire frame.

By reducing the pressure on the denture bases and increasing the over-all denture foundation, less pain and fewer adjustments are involved. The extended coverage utilizes parts of the mandible that have not been affected by surgical procedures and trauma. The nerve endings are normal, and the underlying supporting structures have natural, well-rounded projections. These tissues are capable of assisting in carrying the heaviest loads of mastication.

MUCOSTATICS

Much of the mucostatic principle in regard to the retention of complete lower dentures may be applied to this denture. Some of the advantages of a border seal and ample tissue coverage may be secured with a "pressureless" impression. The soft tissues move with the tissue surface of the denture, and a momentary vacuum is created which aids retention for some patients. The viscosity of the saliva under the denture may be a factor.[2] When flow occurs in a confined liquid, forces arise in a direction to oppose the flow. A lingual bar will not oppose the flow, since it does not contact enough tissue (Fig. 3).

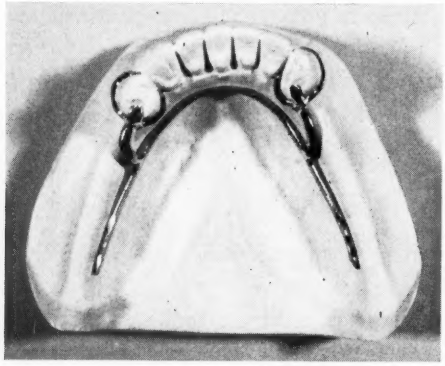

Fig. 2.—The reinforcing wire frame is on the cast. The clasps are gold, soldered or welded to the chrome strengthening wire.

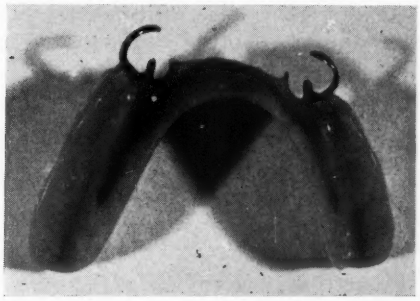

Fig. 3.—The strengthening wire is embedded lengthwise in the plastic base. All of the available denture-bearing tissue surface has been utilized.

POSTERIOR TEETH

Large anatomic teeth in the lower denture offer too much resistance to mastication in addition to increasing the possibility of cuspal interference. The ideal posterior tooth decreases the effect of these pressures and is the narrowest flat tooth available.[3]

The simple geometric form of the French posterior tooth is excellent. In addition, the occlusal surface may be reduced further by trimming a bevel on the buccal surface, thus reducing the surface to contact the opposing upper teeth. The upper teeth may be flat and of a width suitable to the space in the mouth. The occlusal pressure in the lower denture should be directly lingually over the crest of the ridge. When this pressure is controlled and decreased, dentures may be worn successfully even though the ridges are frail and knife edged (Fig. 4).

FUTURE CHANGES

The entire ridge contacting surface may be made of plastic instead of metal when the lingual bar is eliminated. The plastic connector may be adjusted easily,

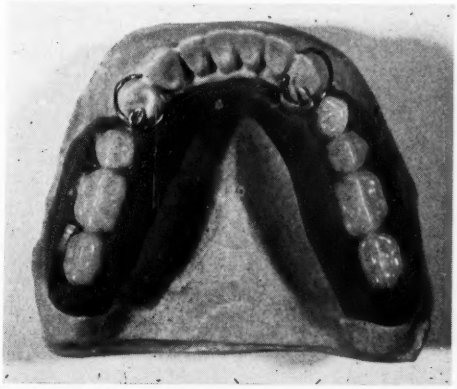

Fig. 4.—The occlusal surface of the posterior teeth is narrow, to reduce occlusal pressures that are transmitted to the denture bases and lingual flange.

resin added, teeth removed or added, or clasps reset or replaced. Relining may compensate for resorption, and the denture can continue its over-all usefulness as more of the natural teeth are lost.

SUMMARY

A removable partial denture technique that covers all available mandibular foundation tissue including that lingual to the anterior teeth has been described. The lingual resin connector is in direct contact with the tissue and is reinforced by a 12 gauge stainless steel wire that is embedded lengthwise in the denture base. This technique reduces the occlusal pressure on the denture bases by transferring part of it to the untraumatized tissue lingual to the lower anterior teeth.

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FIXED PARTIAL DENTURES

FUNCTIONAL OCCLUSION OF THE NATURAL TEETH OF MAN

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THE STUDY OF THE FUNCTION of the natural teeth of man has been associated with the construction and function of dentures. However, the study has dealt mainly with mechanics in the occlusion of teeth and articulators rather than the physiologic and biologic factors involved in the function of the masticatory organ. Bonwill's introduction of an anatomic articulator in 1885 could have been the start of later serious, intensive studies of the problems of occlusion. However, Bonwill did not contribute any observations that later evolved the balanced occlusion theory.[1]

THEORY OF BALANCED OCCLUSION

The theory of balanced occlusion could have had its origin in 1890 when von Spee presented his observations on the function of the natural teeth of man.[2] He wrote, "Since therefore, a forward and backward movement of the mandible takes place in the form of circular movements, it is possible that such movements can be carried out to a greater extent without it being necessary for the rows of the opposing teeth to move away from each other. In this way, one obtains a more perfect use of the grinding movement. A separation of the grinding surfaces must then occur only when there are pronounced projecting corner teeth (cuspids) in the lower and upper jaw. In this case, these teeth overlap. But this can be eliminated by grinding.

"If the chewing surfaces of the teeth were arranged in a plane with the presence of such an articulation of the corner teeth (cuspids), then a parallel gliding of the opposing teeth on each other would not be possible and the grinding of the food would not result. In the case of constructing artificial teeth, this fact should be considered not only for improving the chewing movement, but also to avoid dislodgement of the dentures while chewing."[2]

Von Spee had more to say about the synchronization of condyle movements and occlusion of opposing teeth. He also made a favorable comparison of the *grinding* action of the human dentition with that of the ruminant in contrast to the

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masticating action of the carnivore. His comparison of the grinding action stands out as the function that appealed to the dentists of that era. His reference to the "overbite" (vertical overlap) of the cuspids was overlooked entirely. Subsequent writers on the subject of occlusion continued to expound the desirability of the lateral grinding action with all the antagonist teeth remaining in contact during all eccentric excursions of the mandible.

EVOLUTION OF NATURAL TEETH

The study of the evolution of the natural teeth of the entire primate family does not support von Spee's observations or the balanced occlusion theory. Gregory's study in paleontology depicts the organic changes that have taken place in the anatomy and formula of the natural teeth of the primates.[3] From the Eocene period through the Oligocene and into the mid-Miocene period (20 to 35 million years ago), the dental formula was reduced from $\frac{I\ 2\ C\ 1\ PM\ 4\ M\ 3}{2\ 1\ 4\ 3}$ to $\frac{I\ 2\ C\ 1\ PM\ 2\ M\ 3}{2\ 1\ 2\ 3}$ (Figs. 2 to 4). The number of cuspids and their position in the dental arches have remained constant. The anatomy has undergone some changes, but basically the intended function remains the same.

Cusp formation and intercuspal relations of the teeth of man are basically the same as those of the dentition of the great apes (Figs. 5 and 6). The dentition is designed for a shearing, cutting action and not the grinding action of the herbivore and ruminant. Primarily, the tooth structure is designed for a cutting, shearing action during the mastication of their natural frugivorous, insectivorous, carnivorous diet.

The great apes that still live in their natural, forested environment continue to specialize in a diet of fruits, berries, tender shoots, insects, and eggs. The apes are not flesh eaters, although in captivity they do acquire a liking for meat and a general omnivorous diet.[4] Man, in his early migrations, learned to adapt himself to the diet provided by Nature which varies according to latitudes from the arctics to the tropics.

Man became omnivorous because his struggle for survival depended on it. He learned to eat anything that changing environments produced, provided such foods did not prove to be harmful. The fact that man is omnivorous does not mean that his natural teeth possess a specialized form for an omnivorous diet. Primitive man and recent culturally retarded peoples would have shown the overlap of the cuspids that is seen in western Europeans of today and as shown in *Pithecanthropus robustus* (3 to 6 hundred thousand years ago) (Fig. 7) had they continued to specialize in a soft, nonabrasive frugivorous, insectivorous, carnivorous diet.

STUDY OF ATTRITION

The study of attrition seen in prewhite and recent Australian aborgines by Hector Jones[5] and my own study of the prewhite and present California Indians offer good evidence that the almost immediate change to the edge to edge incisal relation of the anterior teeth from the overlap relation as seen in western Europeans of today was due to environmental factors. Their primitive way of living, the

abrasive nature of their diet, and the use of their teeth as tools and weapons were the contributing factors which caused rapid attrition. The attrition resulted in reduction of the vertical relation of the mandible which in turn resulted in the edge to edge relation of the anterior teeth.

The study of attrition in the prewhite California Indians at various stages of life portrays not only the progressive steps resulting in the edge to edge relation of the anterior teeth but also eccentric temporomandibular movements. These progres-

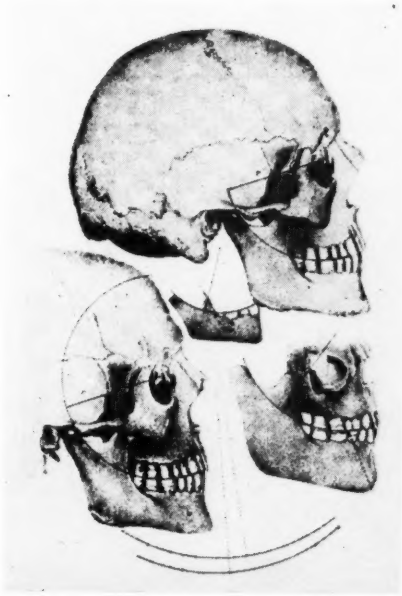

Fig. 1.—The condylar path of the mandible in the glenoid fossa. (By Ferdinard G. von Spee, 1890.)

sive stages parallel those seen in primitive specimens such as Neanderthal and the Tabūn, Skhūl specimens of Mt. Carmel, Palestine, by Keith and McCown[6] (Figs. 8 to 10). Attrition started in the infant stage of life, at the time of weaning. Normally, in the deciduous and successive dentitions, the upper canine teeth are the last to erupt. Usually, by the time these teeth had erupted, attrition of the deciduous molars had reduced the vertical relation sufficiently to establish the edge to edge relation of the deciduous incisors. As the upper deciduous cuspids came into occlusion, the incisal edges were constantly reduced so that they could not assume their normal overlap relation. This permitted wide ranges of lateral and protrusive movements of the mandible.

Figs. 11 and 12 show the occlusal surfaces of the deciduous molars of a Nevada Indian child (5½ to 6 years of age) which are worn flat. Attrition of the upper and lower deciduous lateral incisors and cuspids indicates that an edge to edge occlusion had been established. The occlusal plane of the deciduous molars was reversed, as seen in Fig. 13. The first permanent molars had been erupting but

were not in functional contact. The occulsal surfaces slope lingually and follow the anteroposterior curve of Spee.

The posteroanterior aspects of the maxillary and mandibular teeth of a prewhite California Maidu Indian are seen in Figs. 14 and 15. The approximate age

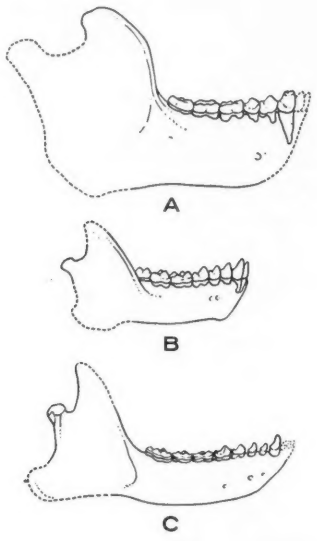

Fig. 2.—The evolution of the human mandible: *(C) Northactus osborno; (B) Parapithecus froasi,* Lower Oligocene, Fayum, Egypt; *(A) Propleopithecus haeckeli,* Lower Oligocene, Fayum, Egypt. (From Gregory, W. K.: Origin and Evolution of the Human Dentition, Baltimore, 1922, Williams & Wilkins Company.)

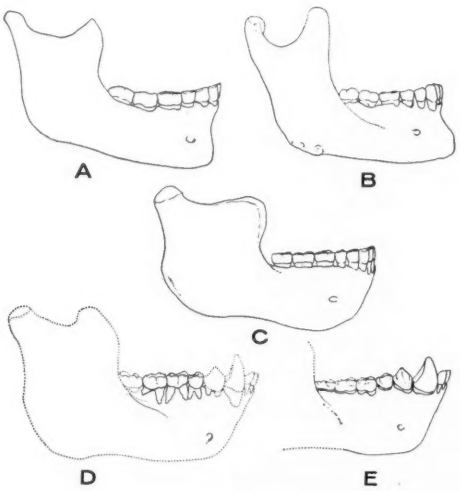

Fig. 3.—The evolution of the human mandible: *(E) Dryopithecus niocene; (D) Sivapithecus miocene; (C) Homo heidelbergensis,* lowest human type, Pleistocene, Germany; *(A) Homo sapiens* var. *australianus,* low human type; *(B)* modern man. (From Gregory, W. K.: Origin and Evolution of the Human Dentition, Baltimore, 1922, Williams & Wilkins Company.)

of this person was 20 to 22 years, about the period of full growth. The lower left third molar is missing. However, the upper third molars and lower right third molar were erupting in a manner similar to that seen today. The upper and lower molars and premolars show a gradual reversal of the occlusal plane. The extent of attrition of the lingual cusps of the upper molars and premolars, the buccal cusps of their antagonists, and the incisors and cuspids indicates an edge to edge relation of the anterior teeth.

The maxillary teeth of another prewhite California Indian in a later stage of life are seen in Figs. 16 to 18. Note that the occlusal plane is reversed, with the occlusal surfaces worn flat and at an angle to the long axes of the premolars and molars. Fatigue and periodontal lesions are present in premolar and molar areas.

The study of the progressive steps of attrition from infancy to old age shows that the normal, functional temporomandibular movement of the mandible is a

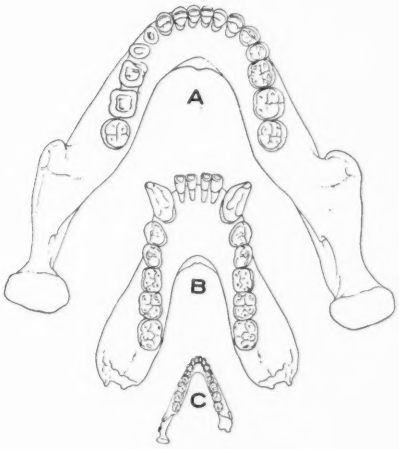

Fig. 4.—The evolution of the human mandible: *(C)* Parapithecus, supertarsoid stage; *(B) Dryopithecus fontani* (by Smith Woodward, 1914); *(A) Homo heidelbergensis.* (From Gregory, W. K.: Origin and Evolution of the Human Dentition, Baltimore, 1922, Williams & Wilkins Company.)

gliding hinge movement. The progressive reversal of the occlusal planes indicates that the functional closing movement of the mandible is backward, medial, and then vertical, into centric occlusion. If the condyles possessed a fixed center of rotation during lateral excursions, attrition would be uniform and would follow the curve of Spee or even the curvature of Monson's 8 inch sphere.

Krogman stated that "according to Todd, our temporomandibular joint is at first slightly hinged, but it is basically gliding."* If the upper cuspids had been able to assume their normal overlap relation, such extensive attrition would not have occurred. Instead, just as we see them in the great apes, the upper cuspids would guide the mandibular teeth medially and vertically, avoiding contact of the opposing teeth until centric occlusion has been attained.

*W. M. Krogman: Personal communication.

The prewhite California Indian enjoyed an omnivorous diet. Rapid attrition of the teeth was not due to the dietary items as much as to the methods of preparing and cooking the food. The use of stone and wooden mortars for grinding the food incorporated considerable amounts of abrasive substances. Leaching acorns in sand pits and heating meal in tightly woven baskets by casting heated stones into it and stirring increased the abrasive content. Cooking meat over open fires incorporated dust and carbon in it. These environmental factors were the principal causes for the rapid attrition of their natural teeth.

When western Europeans migrated to California, the Indians soon adopted their way of living. By so doing, the Indians eliminated the abrasive agents in their food and reduced the rough texture. This sudden change in culture soon eliminated the rapid attrition of their teeth and resulted in an almost immediate change in the functional relation of the natural teeth. The upper incisors and cuspids assumed the overlap relation that Nature intended.

The study of the Australian aborigines by Jones[5] coincides with the study of the California Indian. The immediate change from their primitive culture to the modern European way of life eliminated the abrasive factors which caused rapid attrition of the teeth and reduction in the vertical relation of the mandible. The result of this sudden change was the development of the overlap relation of the upper incisors and cuspids. Evolutionary or organic changes do not develop in such brief periods.

Many individuals who have made studies of primitive specimens and those from retarded cultures have accepted the edge to edge relation of the anterior teeth as a hereditary, normal, functional relation of the natural teeth. But the enamel has been abraded and impaired in such specimens. If the edge to edge relation of the anterior teeth were a hereditary, functional relation, it would be seen in man today, with unabraded, normal tooth structure.

DEVELOPMENT OF EDGE TO EDGE OCCLUSION

The development of the edge to edge occlusion resulting from attrition and reduction of the vertical relation of the mandible is illustrated in Fig. 19. Line *EK* represents the upper central incisor overlapping the lower central incisor, represented by line *IN*. Point *F* is the axis or center of rotation in the vertical closure of the mandible. Point *N* represents the symphysis of the mandible. The upper central incisors are fixed to the maxillae so that the distance of line *EK* to the axis at point *F* is constant and fixed. However, the lower central incisor is fixed to the mandible and moves in a constant arc described by the vertical rotation of the mandible at its axis at *F*. Radius *FN* is much greater than radius *FE*, as shown by comparing arc *D* to point *E*. If the length of the upper central incisor is reduced to point *G* and that of the lower central incisor to point *M*, *M* will describe arc *C* and meet point *G* at point *X*, which is anterior to the incisal edge of the upper central incisor.

The edge to edge relation of upper and lower anterior teeth could not develop if the natural teeth of the primates possessed the compensating factors of crown structure and constant eruption seen in the herbivores and ruminants. The vertical relation of the mandible would remain the same, with constant eruption of the teeth

Fig. 5

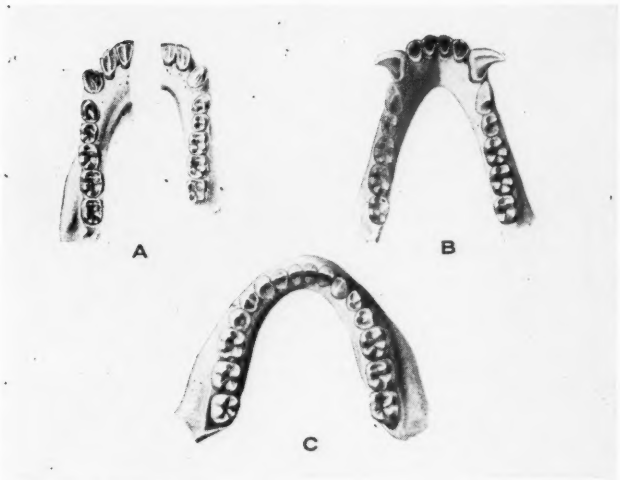

Fig. 6

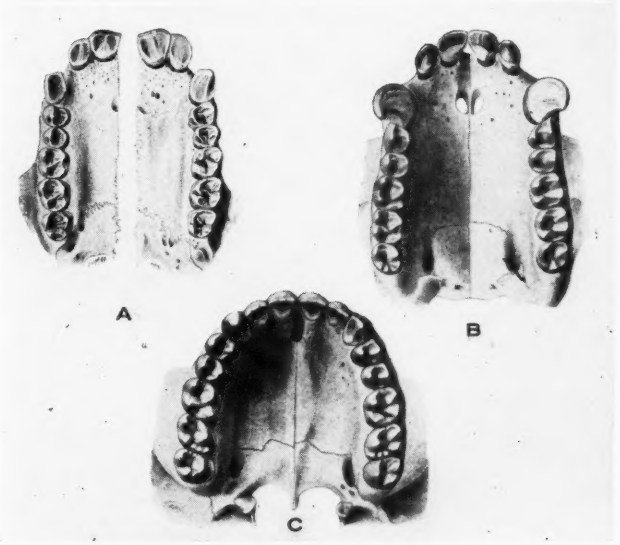

Fig. 5.—*(A)* The mandible of the chimpanzee; *(B)* the mandible of the gibbon; *(C)* the mandible of man. The cusp formation and intercuspal relation are basically similar.

Fig. 6.—*(A)* The maxillary teeth of the chimpanzee; *(B)* the maxillary teeth of the gibbon; *(C)* the maxillary teeth of man. (From Gregory, W. K.: Origin and Evolution of the Human Dentition, Baltimore, 1922, Williams & Wilkins Company.)

to compensate for wear. The radii from the incisal edges of both upper and lower central incisors in relation to the fulcrum or vertical hinge axis would also remain constant. The incisal edges of the lower central incisors would continue to describe the same arc as constant eruption compensated for progressive attrition.

Clinical observation and tests on patients with an edge to edge relation of the anterior teeth because of extensive attrition of the natural teeth have shown that no forward drift of the condyles in the glenoid fossae occurs. The center of vertical

rotation of the condyles at *F* remains constant as the vertical relation of the mandible is opened or closed. Also, there is no mesial drift of the mandibular anterior, premolar, and molar teeth.

FUNCTION OF CUSPIDS

The natural vertical and horizontal overlap relation of the upper cuspids is not strictly a mechanical block. Their function is more than a mechanical guidance of the mandible and mandibular teeth into centric occlusion. The innervation of the periodontal membrane functions in the same manner as the innervation of the tendons, ligaments, muscles, and inner ear. Shock contact of the upper cuspids by the opposing mandibular teeth during eccentric excursions causes transmission of periodontal proprioceptive impulses to the mesencephalic root of the fifth cranial nerve, which in turn alters the motor impulses transmitted to the musculature.

Fig. 7.—The skull of *Pithecanthropus robustus*. (Reconstructed by Dr. F. Weidenreuh.) (From Le Gross Clark, W. E.: History of the Primates, London, 1950, British Museum of Natural History.)

This involuntary action lessens the tension of the musculature, thus reducing the magnitude of the forces being applied.

When the natural overlap relation of the cuspids is eliminated by grinding to obtain a balanced occlusion relation of the natural teeth, one of the most vital physio-

logic factors possessed by any segment of the masticatory organ has been destroyed. If all the natural teeth possessed this involuntary physiologic factor to the same degree as the cuspids, the balanced occlusion theory could be applied without fear of failure of the periodontium and restorations.

Fig. 8.—The mandible of *Homo heidelbergensis.* (After Schoetensack. From Gregory, W. K.: the Origin and Evolution of the Human Dentition, Baltimore, 1922, Williams & Wilkins Company.)

RESOLUTION OF FORCES

A theoretic static relation of the opposing teeth in centric and eccentric contact is see in Figs. 20 and 21. The forces of action and reaction are supposedly in equilibrium. The diagram and resolution of the forces as shown on the lower molar also apply to the upper molar, but in the opposite direction.

The applied opposing forces exerted against the antagonist teeth when they come in contact are supplied by the musculature, mainly the masseter, temporal, and internal pterygoid muscles. The reciprocal forces of reaction are supplied by the periodontium, mainly by the alveolar process and periodontal membrane. In Fig. 20, the opposing teeth are in contact in centric occlusion. In this functional relation, the opposing applied forces *(F)* are parallel to each other and to the long axes of the teeth. The reciprocal forces *(R)* supplied by the periodontium are equal in magnitude and act in the same direction as the applied forces. The rotational effect of the moment about the fulcrum point *(A)* is nil and does not cause tipping of the opposing teeth.

Fig. 21 illustrates the direction and resolution of the opposing forces when the mandible is in eccentric relation and the opposing teeth are in contact on the balanc-

ing side. Both applied and reciprocal forces are resolved into vertical and horizontal components when the forces are applied at an angle to the long axes of the teeth. Theoretically, if the horizontal vector of the applied force *(OP)* in the direction of *O* to *P* were equal to the reciprocal horizontal vector *(PO)* in the direction of *P* to *O* and if the vertical vector of the applied force *(OL)* in the direction of *O* to *L* were equal to the reciprocal vertical vector *(LO)* in the director of *L* to *O*, all opposing components would be equal to each other. This theoretic static state of the opposing forces would not cause a tipping of opposing teeth on their long axes.

However, when the opposing teeth are in this eccentric functional relation, there is an increase of the moment or rotational arm and a reduction of the area of resistance. This functional contact is seen when the upper cuspids are either missing or when their overlap relation is insufficient to increase the vertical dimension to prevent contact of the remaining opposing teeth when mandibular teeth close into centric occlusion.

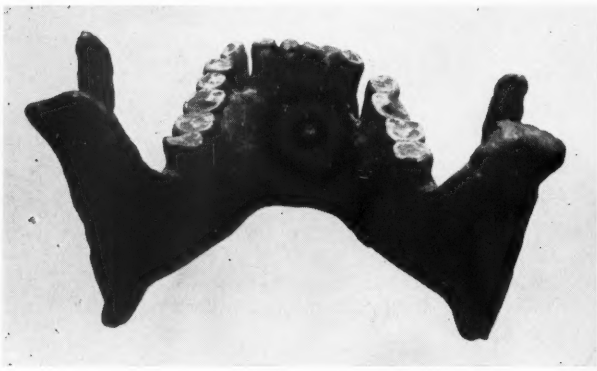

Fig. 9

Fig. 10

Fig. 9.—A posteroanterior aspect of a model of the mandibular teeth of Skhūl V. (Courtesy of T. D. McCown.)

Fig. 10.—The maxillary teeth of Skhūl V. (Courtesy of T. D. McCown.)

MECHANICS OF MASTICATION

Many variables are present in the mechanics of mastication. Some of these are hypo- or hypercalcification of the alveolar process, hypo- or hyperdevelopment of the musculature, and presence of teeth with either long or short roots. The magnitude of the applied forces supplied by the musculature can be determined with a gnathodynomometer. The length of the roots of the teeth can be determined with roentgenograms. However, no one has yet devised an instrument to make test borings of the alveolar bone to determine the magnitude of the reciprocal or resistance forces. Such a procedure is all important in construction and engineering.

To avoid fatigue of the periodontium, the applied forces should be directed parallelly to the long axes of the teeth when the opposing teeth come into functional contact. Any force applied at an angle to the long axis of a tooth, whether

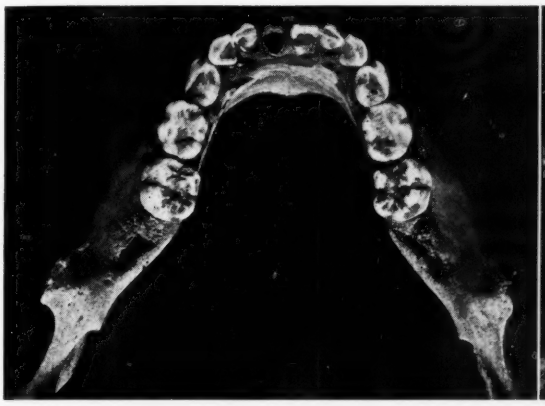

Fig. 11

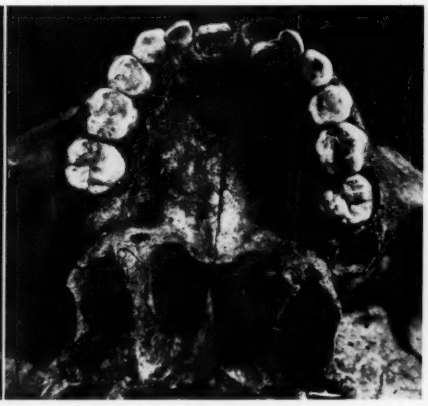

Fig. 12

Fig. 11.—The mandibular teeth of a prewhite Nevada Indian child are worn flat. (Courtesy of the Anthropology Museum, University of California. Catalogue No. 12-3494.)

Fig. 12.—The maxillary teeth of a prewhite Nevada Indian child. (Courtesy of the Anthropology Museum, University of California. Catalogue No. 12-3494.)

it is applied at a 1 or an 89 degree angle, may cause trauma of the periodontium and rapid resorption of the alveolar bone. Nature has taken into account all the variable factors in the primates. Even when the least desirable combination—short roots, hypocalcification, and hypermuscular development—is present, the natural vertical and horizontal overlap of the upper cuspids prevents contacts that could develop horizontal vectors which could cause rapid fatigue of the periodontium or failure of restorations.

PRESERVATION OF NATURAL TEETH

Preservation of the natural teeth and periodontium as well as of the normal function of the entire masticatory organ of man is the goal of dental science. Deviations are the general rule in Nature rather than the exception. The ideal is rarely seen. However, to attain this goal, an ideal functional relation of the natural teeth must be ascertained before the deviations can be detected.

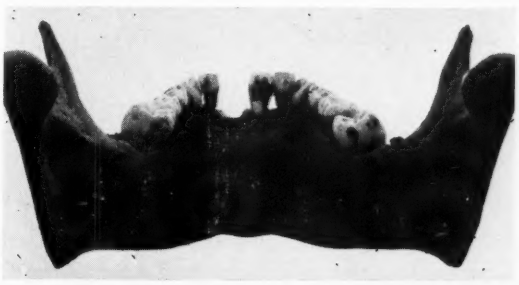

Fig. 13.—The first permanent molars of a prewhite Nevada Indian child slope lingually. (Courtesy of the Anthropology Museum, University of California. Catalogue No. 12-3494.)

There are five teeth on either side of both upper and lower dental arches which determine the ideal functional relation of the natural teeth of man.[7] These are the upper and lower first molars and cuspids and the lower first premolars.

Angles's "key to occlusion" governing the occlusion of the first permanent molars is quite important for growth and development of the dental arches mesiodistally. The mesiobuccal cusp of the upper first molar should occlude in the mesiobuccal groove of the lower first molar. This functional occlusion of the first permanent molars maintains the vertical and centric relation of the mandible during the eruption period of the successive teeth.

Fig. 14

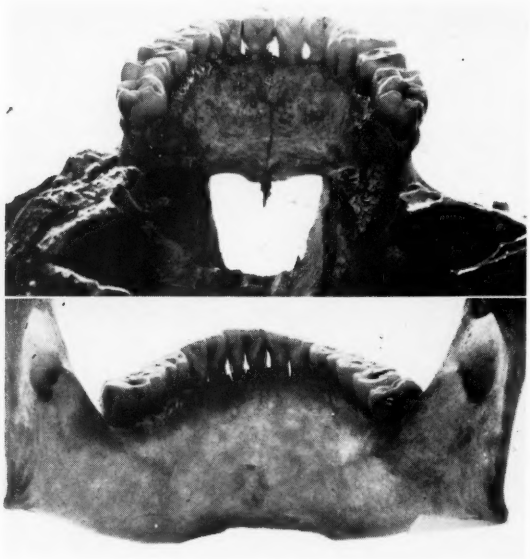

Fig. 15

Fig. 14.—The maxillary teeth of a prewhite California Indian show a gradual reverse of the occlusal plane. (Courtesy of the Anthropology Museum, University of California. Catalogue No. 12-5507.)

Fig. 15.—The extent of attrition of the teeth of a prewhite California Indian indicates an edge to edge relation of the anterior teeth. (Courtesy of the Anthropology Museum, University of California. Catalogue No. 12-5507.)

During lateral excursions of the mandible, the interlocking overlap relation of the upper cuspids with the lower cuspids and lower first premolars guides the mandible into centric relation until the opposing teeth are in centric occlusion. Thus, contact of the remaining opposing teeth that could cause tipping on the long axes is avoided.

Protection of the periodontium of upper and lower incisors is equally important. With the opposing premolars and molars in centric occlusion, as the mandible moves forward, the distoincisal lingual surface and edge of the upper cuspids should glide on the mesiobuccal surface and occlusal ridge of the lower first premolars. The overlap of the upper cuspids must be sufficient to open the vertical relation to

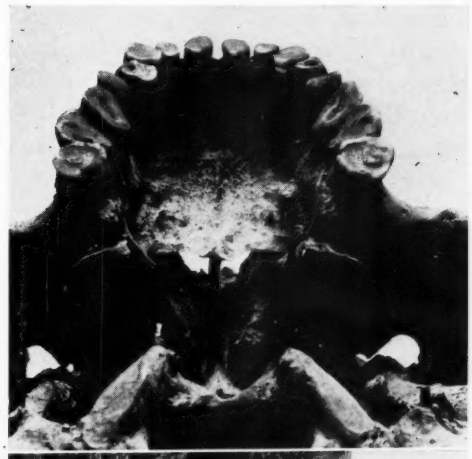

Fig. 16

Fig. 17

Fig. 18

Fig. 16.—The occlusal plane is reversed in an old, prewhite California Indian. (Courtesy of the Anthropology Museum, University of California. Catalogue No. 6791.)
Fig. 17.—Right lateral view of Fig. 16.
Fig. 18.—Left lateral view of Fig. 16.

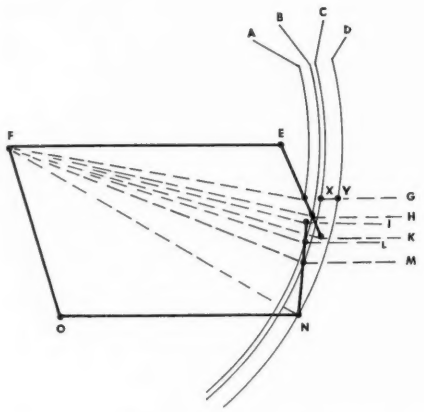

Fig. 19.—An edge to edge relation of the incisors and cuspids developed as a result of a reduction of the vertical dimension of occlusion.

prevent contact of the cusps of opposing premolars and molars. At the same time, contact of upper and lower incisors is avoided until they meet in edge to edge relation. This functional contact of the upper cuspids eliminates the possibility of development of horizontal vectors.

COMPLETE DENTURE OCCLUSION

The ideal functional relation of the natural teeth is in sharp contrast to the ideal functional occlusion of complete dentures. Complete dentures are made up of two units—one upper and one lower. A single deflective occlusal contact can dislodge one or both units during eccentric functional occlusion. Deflective occlusal contacts and cuspal interference must be eliminated for stability of both units.

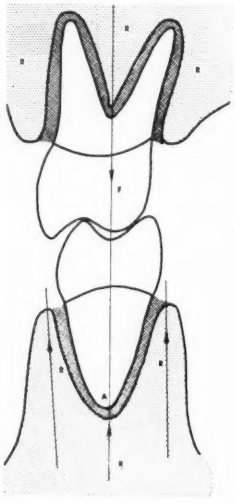

Fig. 20.—The applied forces *(F)* are parallel with long axes of the teeth when the teeth are in centric occlusion. (By A. D'Amico and J. S. Shell.)

However, the complete natural dentition of man consists of *thirty-two separate units,* each acting independently of the others. When the opposing natural premolars and molars are in centric occlusion, each opposing unit is subjected to the full magnitude of the applied forces. If the antagonist teeth still remain in contact in eccentric occlusions without the protection of the upper cuspids (opening of the vertical relation), the same holds true. Such functional contacts at an angle to the long axes of the opposing teeth can develop kinetic horizontal vectors of high magnitude.

CONDYLAR POSITION TO PREVENT TRAUMA

Prevention of trauma in the temporomandibular joint is equally as important as prevention of trauma of the periodontium. The ideal position of the condyles in the glenoid fossae when the opposing teeth are in centric occlusion is in the vertical hinge axis position. In this position, the ligaments are free of tension. This static position of the condyles when the teeth are in centric occlusion is all important in that it is the terminal and starting point of functional movements.

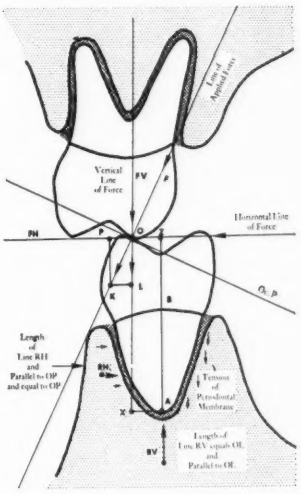

Fig. 21.—The opposing components of force are not equal when the cuspids are missing, or they do not prevent contact of opposing teeth as the teeth come into centric occlusion. The unequal force causes a tipping action on the teeth.

CORRECTION OF OCCLUSION

Correction of any deflective occlusal contacts that would cause the shifting of the condyles from this static position when the opposing teeth come into centric occlusion is the first step in corrective procedure. Diagnostic casts must be properly mounted on an adjustable articulator to determine such contacts. Deflective occlusal contacts that prevent equal distribution of the applied forces parallel to the long axes of all premolars and molars must also be removed before any correction of the vertical and horizontal overlap of the upper cuspids is undertaken.

Superimposing the upper diagnostic cast on the lower diagnostic cast does not mean that the opposing teeth make functional contact in a like manner. Neither does this static state reveal the relation of the teeth to the temporomandibular articulations. Roentgenograms reveal the extent of inflammation of the periodontal membrane and also the presence and extent of periodontal lesions. The direction and progress of alveolar bone resorption give good indications as to the direction of the horizontal vectors that may be causing such resorption. Procedures to attain the ideal functional relation of the natural teeth should never be undertaken before a thorough study of roentgenograms and properly mounted diagnostic casts.

The next step to restore the ideal functional relation of the natural dentition is the correction of the vertical and horizontal overlap of the upper cuspids. This is determined first by the vertical and horizontal overlap of the upper incisor teeth. The protrusive correction of the upper cuspids in relation to the lower cuspids and first premolars should prevent contact of the lower incisors with the upper incisors until they meet edge to edge for shearing action. Then, the horizontal overlap of the upper cuspids is corrected for lateral eccentric occlusions.

INTERLOCKING OCCLUSION

The term interlocking, when used to describe the vertical and horizontal overlap of the upper cuspids, will be misinterpreted by many dentists. They believe interlocking means that with the opposing teeth in full contact in centric occlusion, the upper cuspids will fully lock between the lower cuspids and first premolars to completely immobilize the mandible. Such is not the case. The upper cuspid should have a horizontal overlap of approximately 1 mm. to allow a slight lateral and protrusive eccentric movement when the teeth are in centric occlusion. If the upper cuspids are locked and the mandible is completely immobilized, the effectiveness of the periodontal proprioceptive impulses will be destroyed. Also, locking causes resorption of the labial cortical plate over both upper and lower cuspids and recession of the gingivae around those teeth.

Tight occlusion of incisors and cuspids that completely immobilizes the mandible when all opposing teeth are in centric occlusion often induces bruxism. With the physiologic action of the upper cuspids destroyed, the musculature can exert the full potential magnitude of its forces. Horizontal vectors developed under these conditions create havoc with the periodontium and also, in many instances, with the temporomandibular articulation. A desirable horizontal overlap of the upper incisors and cuspids is extremely important. The extent of the overlap varies with individual patients.

CONSTANT ERUPTION OF TEETH

The horizontal overlap and freedom from contact of upper and lower incisors and cuspids seem to perplex some periodontists and orthodontists. Their big question is the theory of constant eruption. Eventually, they say, constant eruption of these teeth will eliminate the horizontal overlap. Clinically, I have not found this to be true in adult patients. If the upper cuspids are in the ideal functional relation, attrition of the occlusal surfaces of premolars and molars is almost completely

eliminated. If attrition of the occlusal surfaces progresses rapidly, the reduction of the occlusal vertical dimension will most assuredly reduce the horizontal overlap of the upper incisors and cuspids.

Anatomists state that the skull reaches full growth at the average age of 13 to 14 years. Full growth of the body of the maxillae and mandible is not realized until several years later; the age varies with individuals. We are also told that growth and development of the alveolar processes depends on the presence of the natural teeth. Constant eruption of the natural teeth would lead one to believe that this would cause constant growth of the alveolar processes. If this were true, a constant increase in the vertical dimension of the face would be seen.

CONCLUSIONS

The human organism passes through various biologic phases during the full life span. The organism grows and develops by the processes of cell division (mitosis), with constant replacement of worn or fatigued cells from the period of inception, through birth and infancy, and up to the stage of full maturity.

During this favorable period of life, cell growth is greater than cell resorption in alveolar bone. At this stage, periodontal lesions that result from traumatic contact of the opposing teeth are rarely seen.

Traumatic contact of the antagonist teeth accelerates the action of the osteoclasts in the alveolar bone. Failure of osteoblasts to keep pace, with fatigue, gradually results in progressive resorption of the alveolar bone. It is during this later stage of life that the acceleration of bone resorption and rapid development of periodontal lesions occur.

Proper occlusal corrections can be made during the most favorable period if deviations from the ideal functional relation of the natural teeth are detected during the early stages of life. Exceptionally favorable cell replacement of worn cells occurs as fatigue develops during this period of greatest growth and development. With proper corrections during this ideal growth period, it may be possible to reduce the percentage of extractions necessitated by failure of the periodontium from the present estimated 9 out of 10 to a much lower figure.

Photographs by Victor Duran, Life Science Photographer, University of California, Berkeley, Calif.

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USE OF AUXILIARY PERSONNEL IN CONSTRUCTING FIXED PARTIAL PROSTHESES

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THE FIRST MOLAR is the most frequently missing tooth in the permanent dentition. Many occlusal disharmonies and periodontal disorders are initiated or at least aggravated by the loss of this tooth. The loss of other teeth is only slightly less important.

When permanent teeth must be extracted or are missing, they should be replaced. The replacement of one or more missing teeth is best accomplished by a fixed partial prosthesis, providing the number, location, and health of the remaining natural teeth are favorable.

LACK OF USE OF FIXED PARTIAL DENTURES

There are several reasons why dentists are reluctant to educate the patient to the need for a fixed partial denture. First, the laboratory costs, which are higher per unit for a fixed partial denture than for a removable partial denture, may result in a fee that is unfavorable to both the patient and the dentist. Second, perhaps the dentist has not found a commercial dental laboratory that gives uniformly acceptable service. Fear that a remake will be at least an occasional necessity may discourage his enthusiasm to tell the patient of the need for this type of service.

AUXILIARY PERSONNEL

The ideal arrangement for the dentist is to have a dental laboratory technician in his office under direct supervision. However, unless there is a large amount of prosthetic work, the dentist is reluctant to employ an additional person who cannot double at other office duties.

With the present auxiliary personnel, an office procedure that permits fabrication of the entire restoration might be developed or perhaps a man could be employed and trained to be a chair assistant as well as a dental laboratory technician. A moderate investment in refresher courses, equipment, and time would be necessary. The dentist would find that in this atmosphere, the construction of fixed partial prostheses is a gratifying part of his practice.

FIXED PARTIAL DENTURE TECHNIQUE

There are several indirect techniques for making fixed restorations that are acceptable for office use. I prefer a reversible hydrocolloid technique.

The dentist pours the first section of the master cast and positions the dowel pins while the artificial stone is soft, immediately after making the impression of the prepared teeth (Fig. 1). This requires about 5 minutes for a three or four unit fixed restoration.

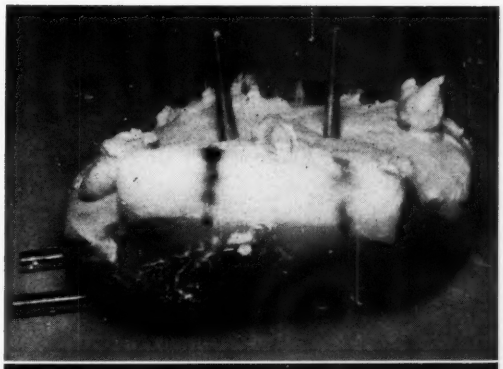

Fig. 1

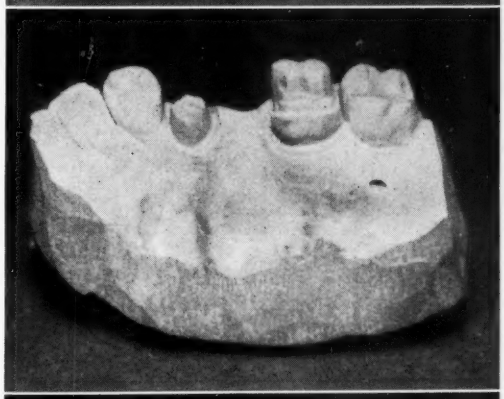

Fig. 2

Fig. 3

Fig. 1.—The part of the cast which represents the teeth is poured in artificial stone and the dowel pins are positioned.

Fig. 2.—The cast is completed with a different colored stone after a separating medium is applied around the dowel pins.

Fig. 3.—Vertical saw cuts are made through the first color of stone to free the individual dies.

Fig. 4 Fig. 5

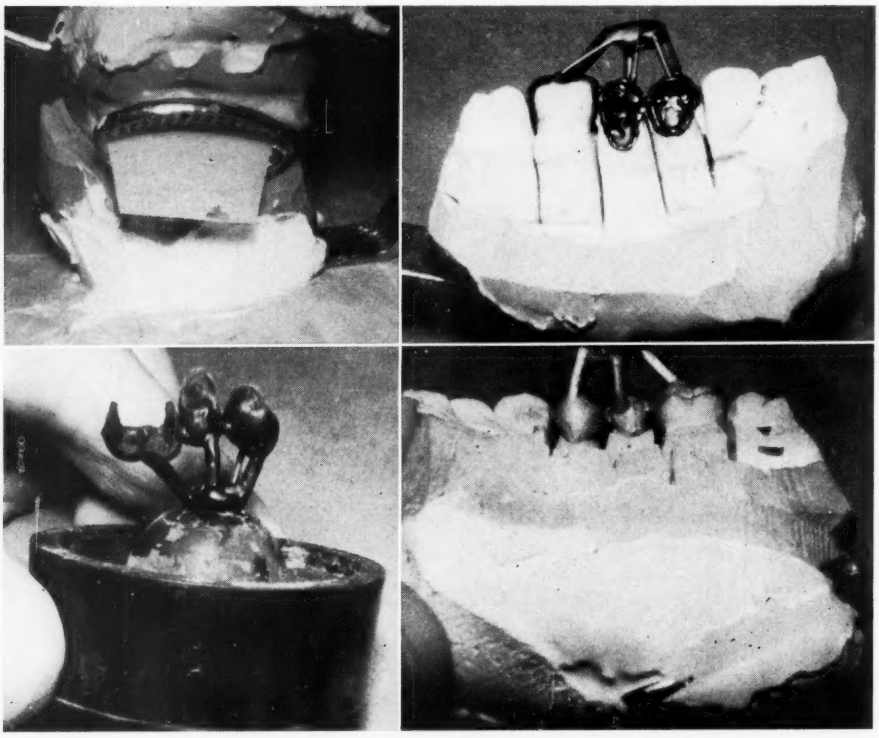

Fig. 6 Fig. 7

Fig. 4.—The casts are mounted on an articulator.
Fig. 5.—The wax patterns are completed, and the sprues are attached.
Fig. 6.—The wax pattern is attached to the crucible former.
Fig. 7.—The unpolished casting is on the master cast.

After the first section of the master cast has set, the assistant applies a separating medium* around the dowel pins. Then the cast is completed by applying a different colored artificial stone around the ends of the dowel pins (Fig. 2).

The dentist makes the necessary cuts to free the individual dies after allowing the stone to set (Fig. 3). He also trims the dies to the exact margins of the preparation since he is familiar with their outlines. The dies are trimmed with a carborundum disk and a No. 11 Bard-Parker blade for the finer trimming. Magnifying loops aid in this procedure.

With a little practice, the assistant can relate the casts with an interocclusal record and attach them to an articulator with plaster (Fig. 4). The assistant lubricates the dies and the opposing stone teeth and flows casting wax into the abutment preparations. Then she carves the patterns to the best of her ability and removes the rough wax pattern from the dies to be certain that they will draw.

*Super-Sep.

The dentist refines the carving and marginal adaptation of the wax patterns and develops the wax pattern for the pontic. Then the individual wax patterns of the abutments and pontics are luted together at the contact areas. One or two wax sprues are attached to each unit and joined so that they can be attached later to the crucible former (Fig. 5). The sprues are made of 12 to 14 gauge wire and should be kept as short as possible.

The entire wax pattern is gently removed slightly from the master cast on the first attempt. Then the pattern is reseated, and all margins are checked for distortion. The wax pattern of the restoration is attached to the crucible former as a single unit (Fig. 6).

The assistant can readily learn to invest, cast, finish, and polish the fixed partial denture (Fig. 7). A technique of casting to dimension must be employed.

A fixed partial denture cast in one piece results in a marginal fit equal to that of a single inlay casting. Thus the need for assembling, investing, and soldering of the elements of the restoration is eliminated. The elimination of these procedures reduces the possibilities of error that have been encountered in this phase.

SUMMARY

Dentists can offer a more complete service to patients by using fixed partial prostheses where they are indicated.

If a full or part time dental laboratory technician is not available, an assistant can be trained to do some or most of the laboratory procedures. In time, with incentive and ability, the assistant can do nearly all of the laboratory procedures.

The laboratory procedure can be altered by casting the entire fixed partial denture in one piece without sacrificing the quality of the restoration.

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ABUTMENTS FOR FULL MOUTH SPLINTING

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CONSERVATISM IN THOUGHT AND TECHNIQUE, where practiced in the realm of uncertainty, is naturally the most sensible manner of approach. However, fixed partial dentures can survive successfully even though the abutments have very few favorable qualifications. This could be proved by observing results over a period of years.

In this article, I shall discuss overconservatism pertaining to qualified fixed partial denture abutments.

Only by evaluation of many fixed restorations can the prognosis of fixed partial dentures supported by "poor risk" abutments be determined.

A critical survey of abutment possibilities may be made more emphatic or dramatic by comparison of the negative aspects, the deficiencies and shortcomings, with the positive picture. This will bring out the striking importance of dependable and adequate preparation for efficient retention and for the passive insertion and fit of fixed restorations.

BASIC QUALIFICATIONS FOR ABUTMENT TEETH

To qualify as an abutment, a tooth should (1) have excellent or good bone support, (2) have a healthy periodontal membrane and surrounding soft tissues, (3) be long rooted, with divergent roots if it is multirooted, (4) have no mesial tipping or rotations, (5) be immobile, and (6) be vital.

These are the qualifications for the ideal situation. Certainly, if the state of health of the supporting mechanism of the abutments were ideal, if the abutments were prepared and treated in the proper manner, and if there existed no general systemic disturbances, the prognosis would be excellent. However, this does not mean that teeth with poorer dental health cannot be successful abutments.

Contrary to previous beliefs, (1) the inside abutments can have poor bone support with class III mobility, (2) the periodontal membrane can be temporarily in an inflamed or edematous state, (3) the roots can be short and even fused in multirooted teeth, (4) there can be a little or even a great deal of mesial tipping of lower molars and rotations of bicuspids, (5) the abutments can be mobile, and (6) the teeth can be pulpless and still be successful abutments.

CORRELATION OF THE ABUTMENT PREPARATION AND RESTORATION

An abutment for a large bridge will fail if its preparation and restoration are not correlated with one another. If they are inconsistent, failure will follow.[1]

When two or more teeth are tied together as supports for a fixed partial denture, the problem becomes complicated and requires careful solution. Various mechanical forces become involved in the plan for which due provision must be made.

ABUTMENT PREPARATION

The following procedures should be carefully carried out in making acceptable tooth preparations: (1) the abutment preparations must be tapered buccolingually and mesiodistally, (2) the preparations should be cylindric in shape and without line angles, (3) when more than one abutment is involved, they must be parallel to one another in every aspect, (4) all abutments that are either buccal or lingual to the arch should be ground so the pontics can be placed as nearly perpendicularly to the crest of the ridge as possible, even though it entails root canal therapy, (5) the abutments should have sufficient retentive form to offset counteracting stresses, (6) the preparations should facilitate the restoration of normal tooth form, (7) the preparations should permit esthetic replacement of those missing teeth, (8) each casting should go snugly into position and the margins of the casting should fit accurately with those of the prepared abutment finishing line, and (9) the completed fixed partial denture should fit in place passively.

BREAKDOWN OF ABUTMENT SUPPORT

Traumatic occlusion, habits, and systemic conditions cause abutment teeth to loosen. If teeth can be kept immobile, if the periodontal membrane and surrounding soft tissues remain in a relatively healthy state, and if there is no future systemic osseous breakdown in the "bone factor," the chances for success in the splinting or bridging of the remaining teeth in the arch are greatly enhanced.

PROSTHODONTIC EQUILIBRATION VERSUS HEALTH OF ABUTMENTS

Occlusal equilibration of the completed restoration, rather than the state of health of the abutments before their preparation, will determine the life of the abutment teeth. A relatively strong and long-rooted tooth with little tipping can fail as an abutment if it is not prepared parallelly with the other abutments or if the fixed partial denture is not balanced and equilibrated correctly with the opposing teeth. Similarly, a poor risk tooth can be a successful abutment if the preparations and restorations are properly correlated and if the occlusion is accurately equilibrated.

TOOTH MOBILITY AS A FACTOR

Tylman[2] said, "The placement of a fixed bridge is sometimes recommended as a therapeutic measure in those instances where one of the abutment teeth is extremely loose in its socket."

Occlusal trauma is the most important cause of tooth mobility. The occlusion may be traumatic while in centric or lateral positions. Edema occurs frequently with trauma. The edema may be of short duration, such as in acute conditions where it will disappear soon after the trauma is removed. Or the edema may be of long

standing, with much bone loss and tissue inflammation, if left alone. However, with the elimination of the occlusal trauma and the edema, most of these teeth also will become tight.

If there is occlusal trauma as a result of habits such as bruxism, nail biting, pipe smoking, etc., where facets can be seen on the surfaces of the loose teeth, the occlusion can be equilibrated and the bad habits eliminated prior to complete mouth reconstruction.

BONE LOSS AROUND ABUTMENTS

The bone loss can be due to either senile alveolar atrophy, periodontal disease resulting from trauma, etc., or systemic conditions.[3] In senile alveolar atrophy, the teeth have resisted periodontal diseases all of the patient's life. The bone has been lost over a long period of years, and the teeth are usually tight, with little or no inflammation about them. The prognosis for these teeth as abutments is usually good.

If the bone loss is associated with a more rapid periodontal disease, the causative factors must be eliminated before the prognosis can be made.

RELATIVE ABUTMENT MOBILITY

If all of the abutments have equal mobility, the prognosis can be good provided there is a fairly equal distribution of them in the arch.

Some abutments may have more mobility than others somewhere within the *inner framework* of the splint. These teeth can still be used as abutments in the splint and will probably tighten with the help of the other, stronger abutments.

Mobility in the terminal abutments can present a problem, especially if the anterior splinted abutments cannot resist the lateral stresses brought to bear upon them. The root to crown relationship of terminal abutments is an important factor in the prognosis. If the roots are fused and short, the chance for success is poorer than if the roots were long and flanged out.

PAIN AS A FACTOR IN ABUTMENT ACCEPTANCE

If painful teeth can be treated and the pain eliminated, the teeth usually can remain in the mouth. In the past, if a tooth could not be treated "according to the books," it was extracted. This is so very far from correct. Teeth can be used for abutments regardless of whether or not a tooth is pulpless. A tooth can and should remain in the mouth and be used as an abutment, unless it is excessively loose.

TIPPED TEETH

Normally, mesially tipped lower molars (the mesial teeth adjacent to which have been lost) should be no problem when used as abutments.

If a tooth is drastically tipped, with little or no mobility, the prognosis is still excellent. The tooth should be prepared by cutting away the mesial proximal surface to make this surface parallel with the other preparations. Once this is accomplished, the tooth automatically becomes parallel in its mesiodistal relationship with

out disturbing the distoproximal surface. However, root canal therapy may be necessary because of an exposure of a vital pulp. Otherwise, a telescopic* crown can be made to avoid damage to the pulp. The buccolingual relationship presents no problem.

Where a fixed partial denture is placed on a tipped posterior abutment tooth, the bridge causes undue leverage in a forward direction, with the strain being placed on the anterior abutment. The force of the occlusion applied in a vertical direction is received unfavorably by the tipped tooth, and this causes an undue anterior thrust. This excessive force can be withstood by soldering two anterior abutment castings together in partial splints. Since more abutments are included in full arch splints, this force in a mesial direction is reduced to a minimum.

Tylman[2] said that teeth tipped beyond 24 degrees as a rule should not be used for fixed partial denture abutments. If they are, the vertical stresses on the restoration will not be transmitted in the direction of the long axis of the tooth. This will result in the crushing of the periodontal membrane and a breakdown of the tissues on the mesial aspect of the abutment tooth. I do not fully agree. If this breakdown and crushing of tissue occurs when tipped abutments are used with at least two anterior abutments splinted together at the other end of the restoration, there should be even more breakdown by leaving the tipped tooth alone. By splinting the tipped tooth and keeping it immobile by closing the spaces, the breakdown could not occur as rapidly as when the tooth is left alone.

TOOTH MOVEMENTS

Teeth move vertically, buccolingually, and mesiodistally. By the use of a fixed full arch splint supported by abutments on both sides of the arch, tooth movements can be reduced to the minimum.

The vertical movement which is due to an occlusal overload can be eliminated by removing the occlusal trauma. The buccolingual tooth movement can be reduced by equilibrating the occlusion in centric and eccentric positions. The mesiodistal tooth movements can be eliminated by the solder joints and contact areas of the teeth in the splint.

CONCLUSIONS

Although ideal abutments for fixed partial dentures should be used when they are available, successful full mouth reconstruction can be accomplished with abutments of lesser quality for some patients.

As few as four teeth strategically situated in the arch can provide the basis for a successful full arch splint even though they may not meet all of the requirements of ideal abutment teeth.

When the prosthesis is to be constructed on these less than ideal abutment teeth, the possibility of its failure should be thoroughly discussed with the patient before the work is started.

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*A gold coping cemented over a drastically tipped mandibular molar which is constructed to be parallel with the remaining prepared abutments. This prevents exposure of the pulp of the tooth.

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GOLD PLATING TO ENHANCE THE APPEARANCE OF PORCELAIN-FACED CROWNS

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PORCELAIN FUSED TO GOLD CROWNS has a more lifelike appearance if the metal to which the porcelain is fired has been plated with pure gold prior to firing. The soft yellow background of the plating enhances the translucency of the porcelain, and it permits selection of shades that match the natural teeth.

Color matching is made more accurate if the dentist makes his own shade guide. Tooth-shaped tabs of the metal are gold plated and fired with the various shades of porcelain. These tabs give a shade guide that accurately foretells the shade of the finished crown.

DESIGN OF CASTINGS

Since the pure gold that is plated on the interface surface does not oxidize during firing, the bond between the porcelain and gold is probably mechanical only. Therefore, retention for the porcelain is provided in limited areas. The pattern is carved with definite angles at the junctions of the incisal, mesial, distal, and gingival surfaces with the labial plane,[1] and tiny plastic beads are spaced in these angles (Fig. 1). The plastic beads are eliminated during the burnout and form definite spots of retention on the casting (Fig. 2).

PREPARING THE CASTING PRIOR TO PLATING

The fit of the casting is verified, the occlusion adjusted, and the casting polished. The part of the casting that will contain the facing is not polished but is bur finished. Successful plating requires perfect cleanness of the casting. Surfaces not to be plated must be blocked out, and an electrical connection must be established.

The casting is thoroughly scrubbed and is placed in hydrofluoric acid for several hours or overnight. The acid is flushed off the casting with tap water.

A length of wire (a section of paper clip) is bent into an elongated U, and the free ends are adjusted so they will slip into the crown under slight tension. Inlay wax is flowed into the crown after the wire has been positioned. The wire serves as an electrical connection to the crown and also as a handle.

Inlay wax is flowed onto all surfaces of the crown except that which is to be plated. The wax must be tightly sealed to the metal at the gingival margin to prevent leakage. The wax is continued up onto the paper clip to prevent a deposition of gold on it (Fig. 3).

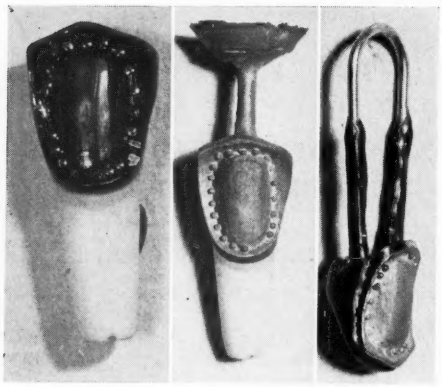

Fig. 1 Fig. 2 Fig. 3

Fig. 1.—Plastic beads are placed around the window of the wax pattern.
Fig. 2.—The beads supply added retention for the porcelain.
Fig. 3.—All surfaces not to be plated are covered with inlay wax, and a paper clip is used to make the electrical connection.

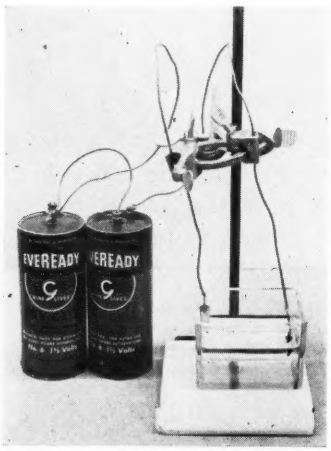

Fig. 4.—The apparatus used to plate the crowns is of simple design.

The wax-covered crown is thoroughly flushed with distilled water and placed into the plating solution. Electrical connection with the negative pole is made to the paper clip. Contamination of the facing surface of the crown by wax or grease can be corrected by dipping the crown into aqua regia for a few seconds before the final rinsing with distilled water.

GOLD PLATING

There are many variables and unknown factors in metal plating. A simple method will be presented that gives consistent results for plating pure gold onto casting metals.* The apparatus is simple.

*Permium 22, Ceramco No. 1, and Ney-Oro P-16.

A solution of gold cyanide which can be purchased commercially is used as the plating solution. The solution can be made with simple laboratory equipment, but a ventilating hood is needed for boiling acid. The solution can be used indefinitely, provided it does not become contaminated. Foreign objects should never be placed in the solution unless they are coated with inlay wax to a level substantially above the solution level. The solution must be covered or bottled when not in use, and distilled water is added periodically to maintain the original level. Strips of tape are placed on the containers to mark the original levels of the solution.

Fig. 5.—The facing surface is plated.

Fig. 6.—Note the color contrast of the plated and nonplated surfaces.

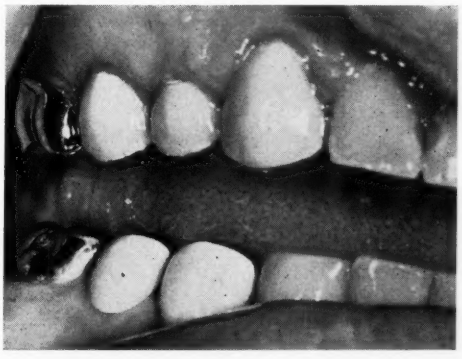

Fig. 7.—The three upper crowns are plated, while the two lower crowns are nonplated. Note the difference in shade between the upper and lower crowns.

The anode is a pure gold casting which is tapered slightly in all dimensions toward the end to be submerged. A hole is drilled in the large end of the casting, and a wire is placed through the hole and tightened to serve as the electrical connection for the positive pole. The tapered shape of the anode permits a more even dissolution when a number of crowns are to be plated. A 2 pennyweight strip of pure gold plate can be used as the anode if a small number of crowns are to be plated. A small anode lasts for a surprisingly long period of time (Fig. 4).

VARIABLES THAT AFFECT PLATING

Many variables in the plating procedure are unknown, however the following factors should be observed: (1) The anode surface immersed in the solution should be approximately equal to the surface of the crown to be plated. (2) The solution is kept at room temperature to avoid harming the wax coatings of the crowns to be plated. (3) At least ½ pint of gold cyanide solution is used for each crown to be plated. (4) The current will be within a satisfactory range when two 1½ volt dry cell batteries are connected in series. (5) The plating time for the castings is 2 to 3 hours, depending upon the current used.*

HANDLING THE PLATED CROWN

When the plating is completed, the wax that covers the nonplated surfaces is eliminated, and the casting is cleaned. The crown is test fired in the furnace to 1,800° F. prior to porcelain application and is allowed to cool. The plated surface will be a soft yellow color as contrasted with the much darker body of the crown (Figs. 5 and 6). The crown is now ready for the addition of the porcelain.

The opaque layer of porcelain is applied and fired. As an extra precaution, the opaque material should also be applied to the tips of the retention beads so they will not show through the body porcelain of the finished crown. The porcelain veneer is completed, and the crown is cemented into place in the mouth (Fig. 7).

SUMMARY

Lifelike shades of crowns composed of porcelain fused to metal can be consistently obtained if shade guide tabs are constructed and all interface surfaces are gold plated before firing the porcelain to the metal. The interface surface of full crowns must be correctly designed to provide effective retention of the porcelain veneer. A method for gold plating the facing surfaces was described.

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*An amount 15 to 20 ma. seems to be optimal. Better plating control can be secured by including a small variable resistor in the circuit.

ADAPTING ROOT FORMS TO WORKING DIES

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HUMAN TEETH CONVERGE from the circumferential height of contour of the anatomic crown to the root end. Since a tooth properly prepared to receive a porcelain jacket crown is convergent immediately rootward from the shoulder cavosurface angle, accurate hard surface reproduction of this area in a die prevents the subsequent withdrawal of a platinum matrix. Consequently, the root form of the die must exhibit divergence, or an "apron," throughout its circumference for about 2 mm. rootward from the cavosurface angle.

This subject will be examined as it applies to the make-up of a working die to receive the platinum matrix in porcelain jacket crown construction. However, the adaptation of the root form applies as well to all time-set powder-liquid mixture die materials regardless of the type of tooth preparation.

LABORATORY TECHNIQUE

An impression made with an elastic impression material provides the negative record of the tooth preparation. Sharp detail of the subgingival cavosurface angle form, be it shoulder, chamfer, or otherwise, is a specific requirement (Figs. 1 and 5).

The die is poured in the impression in hemihydrated class II artificial stone, which gives a positive reproduction of the prepared tooth (Figs. 2 and 5). Some surplus of the artificial stone is piled up within the root part of the die for about ⅜ inch.

The surplus material in the root section is trimmed circumferentially to conform approximately to the natural root form of the prepared tooth. The critical cavosurface angle must not be damaged. The root form of the stone die is cut perpendicularly to the long axis of the tooth to leave a band at least 2 mm. wide rootward beyond the shoulder cavosurface angle. This positive stone die with the short, flat root end is cemented to a glass or plastic plate with a fast-setting acrylic resin cement (Figs. 2 and 5). A rigid, strong bond *must* be obtained between the stone die and the surface plate.

The gingival band (apron area) between the shoulder cavosurface angle and the surface of the flat plate is filled with inlay wax and shaped to allow for subsequent removal of a platinum matrix (Figs. 2 and 5).

An impression is made of the wax modified artificial stone die using either polysulfide or silicone rubber to permit electroplating in the laboratory. The rubber

Presented as a table clinic before the American Academy of Crown and Bridge Prosthodontics in Chicago, Ill.
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impression material is contained within an oversized stock copper band to which a diametrically oversized copper or brass cap washer has been attached with soft solder. The cap facilitates the removal of the impression from the stone die, which is held firmly to the underlying surface plate. The metallic cap also assists in making up the cathode circuit for the electroforming procedure. The flat surface plate brought into contact with the unfestooned open end of the copper band cuts away almost all of the excess rubber-base impression material (Figs. 3 and 5).

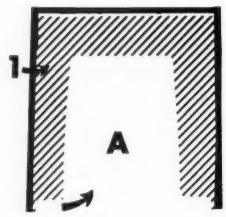

Fig. 1.—A closed band impression *(1)* is made of an elastic impression material. The tooth preparation *(A)* must be recorded accurately with sharp cavosurface angle detail.

The rubber-base impression made in the laboratory is electroplated with silver (Figs. 3 and 5). The internal core of the electroformed silver plate is filled with some dimensionally stable, solidly set material that will resist the forces in adaptation of the platinum matrix. A low-fusing bismuth-base alloy (in rod form) that melts at 130° to 140° F.* is used (Fig. 5). The rod is heated with a soldering iron or in a similar manner, and the liquefied metal is allowed to drop into the open end of the plated impression until it is slightly overfilled (Figs. 3 and 5). A small heat-controlled modeler's electric soldering iron or a heavy dental hand instrument heated in an open flame can be used. This method does not cause overheating and consequently does not distort the underlying silver core. A heated volume of "160" or Melotte's metal (200° F.) poured into the impression damages and sometimes partially melts the plating.

*Dr. Ray's Low-Fusing Metal.

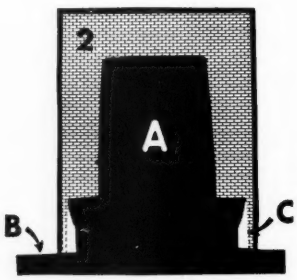

Fig. 2.—The laboratory die is constructed of artificial stone in the impression *(2)*: *(A)* the stone die; *(B)* the glass or plastic base; *(C)* the natural rootward undercut from the die cavosurface angle, filled with inlay wax to make a divergent apron for the die.

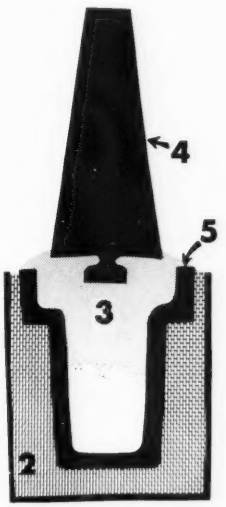

Fig. 3.—The components of the root form shown schematically: *(2)* the laboratory impression; *(3)* the low-fusing metal core fill; *(4)* the preformed and cast root form adaptation; *(5)* the silver plate.

To make the most efficient use of the method, a number of cast metal preformed working die roots or posts should be available. Their design should be adaptable to the common indirect laboratory procedures used in making up working casts. Consistent rootward conical convergence of a smooth surface indexed by flattening at least one side meets the requirement for these die roots.

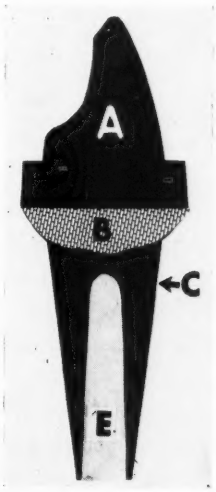

Fig. 4.—The working die for a porcelain jacket crown is completed: *(A)* the silver-plated die of the prepared tooth and the apron; *(B)* the low-fusing metal core fill; *(C)* the root form adaptation; *(E)* the indexing flat surface on the side of the root form.

Four sizes of die roots are needed, with diameters equal to the inside diameter of Nos. 4, 6, 9, and 14 standard size copper bands. A single size root form similar to this design is available commercially.*

Patterns for these die root forms may be made of dental wax or quick-curing acrylic resin rolled into a taper on a glass slab. The pattern should be ¾ to 1 inch in length. A series of resin root forms (or posts) that can be invested and burned out for casting are available.†

An excess of the pattern material into which a sprue pin can be correctly related is formed on the end of the root form with the largest diameter. When cast, this excess material serves as an undercut for the mechanical attachment of the root form to the die. A high-fusing metal technique alloy such as "K" or silver technique metal or brass brazing rod is used to cast the root forms. Most of these metals melt at about 1,700° F. (Figs. 3 and 5).

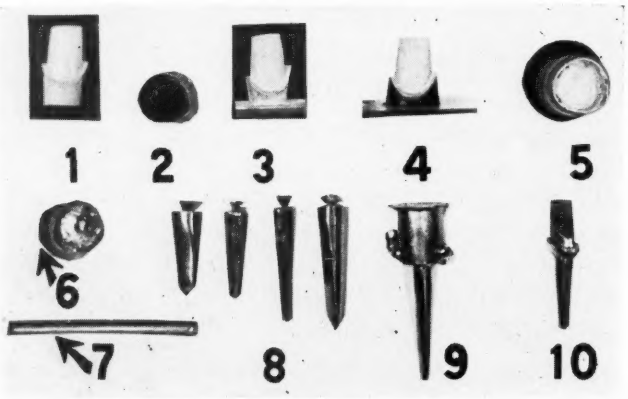

Fig. 5.—The technique and procedure: *(1)* the tooth preparation; *(2)* the impression of the prepared tooth; *(3)* the laboratory artificial stone die; *(4)* the wax fill-in rootward from the cavosurface angle, and the stone die cemented to the surface plate; *(5)* the silver-plated impression; *(6)* the low-fusing metal fill-in; *(7)* the finished rod of low-fusing metal; *(8)* four preformed and cast metal root forms; *(9)* the cast root form adapted to the low-fusing metal fill; *(10)* the completed working die for porcelain jacket crown construction.

A polished cast metal root form the wide diameter of which is slightly smaller than the greatest diameter of the base of the die is selected. The root form is heated in an open flame, and the undercut nob on the root form melts into the low-fusing metal of the die. The root form is retained in the desired perpendicular relationship to the die until the surrounding metal has solidified or until the die stone has set (Figs. 3 and 5).

Some of the die material, or "electroform fill," will be displaced by the insertion of the root form or post. This excess is trimmed away, and the working die is complete (Figs. 4 and 5).

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*Ney precision dowel pin.
†Assorted Acralite die posts.

ADVANTAGES

1. The procedure described for constructing root forms for working dies has certain advantages. The critical apron area of the die in porcelain jacket crown construction is under preform control before the die is hard surfaced or plated. The need for insecure patchwork in this area on a completed die is eliminated.

2. The conical taper of the root form, as well as the length of the working roots, may be standardized if desired.

3. The time-consuming repeated trimming of large bulks of root form materials to meet necessary laboratory requirements is eliminated.

4. The preformed cast metal post may be adapted to low-fusing metals or to time-set powder-liquid die mixtures by positioning the root form before the set occurs.

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COMPRESSIVE STRENGTH OF AMALGAM AS INFLUENCED BY DIFFERENT CONDENSATION FORCES

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ONE OF THE HIGHLY DESIRABLE PROPERTIES of dental amalgam restorations is adequate compressive strength. The development of this strength soon after condensation is thought to have clinical significance in potentially reducing fracture or damage to the restoration before it has developed its maximum resistance to biting forces. It has long been recognized that different amalgam alloys possess different values for compressive strength and rates at which the maximum strength is developed. One of the factors influencing the ultimate compressive strength is generally considered to be the amount of force applied in the condensation operation during placement of an amalgam restoration. There have been relatively few studies to demonstrate the orderly variation in compressive strength of amalgam as a result of alteration in condensation forces, although numerous studies have shown that the dimensional changes in setting, flow, compressive strength, and mercury content are modified by different condensation forces.

The difficulties caused by poor condensation practices and low forces of condensation have been recognized by Hollenback,[1] Mosteller,[2] Ryge,[3] and Coy and Liebig.[4] It has been shown by Phillips and Healey,[5] Taylor and associates,[6] and Ward and Scott[7] that light packing forces will result in amalgam that overexpands, flows excessively, and possesses reduced strength. It has been thought that excess mercury resulting from low condensation forces accounts for the increased flow and expansion that are generally observed. The lack of homogeneity in the amalgam resulting from low condensation forces may be responsible for some loss of strength and inconsistency in results.

Since both the rate of development of strength in the amalgam mass and the ultimate strength of the amalgam are important, this study had two primary purposes. The first was to determine the influence of condensation forces on the

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Strength values reported are from a thesis submitted by E. L. Liatukas in partial fulfillment of the requirements for a master of science degree in dentistry at the University of Michigan, 1959.

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compressive strength of several popular amalgam alloys recognized as giving serviceable clinical restorations. The second was to determine the effect of condensation forces on the rate of development of compressive strength in the amalgam. A related purpose was to observe any correlation that may exist between the final mercury content of the amalgam and either the final strength or the rate at which the strength is developed. Other factors related to the presence or absence of zinc in the amalgam alloy and the accepted particle size of the alloy were observed as they are related to the strength characteristics of the amalgam.

MATERIALS AND METHODS

Seven popular alloys, purchased in the commercial market, were used for the tests described in this study.* To ensure consistent results, sufficient quantities of each alloy with the same batch number were purchased, and all products were certified to meet the requirements of A.D.A. specification No. 1. Of the alloys, two do not contain zinc and two have an alloy particle size larger than the remaining products, which are described as being fine cut (see Table I). No effort was made to measure the relative particle size or the specific surface area of the alloy particles. Microscopic examination indicated differences to exist, however, in particle size of different alloys, and those described as having fine particle sizes were observed to be smaller than those described as regular in particle size. Variations were observed to exist in both the size and shape of particles of products claimed to represent fine particles. Further studies of the full significance of alloy particle size should prove useful.

All products were mixed according to the manufacturers' instructions, with the recommended alloy : mercury ratio. The mixing was performed with a mechanical amalgamator using a large plastic capsule with a large metal pestle. The trituration time was kept constant for all mixes as established for each specific alloy. The test cylinder, 4 by 8 mm., was prepared in a split steel mold by use of hand condensation. During the hand condensation, using a 2 mm. diameter round, smooth face condenser, the mold was mounted on a gauge designed to record the force applied. Four condensation forces applied to the condenser were used with each product: 8 to 10, 6 to 8, 4 to 6, and 2 to 4 pounds. Five samples for each load application were prepared for each alloy, and the average value is reported to the nearest 100 p.s.i. in Tables I and II. All samples were prepared and tested at room temperature. The compressive strength was determined at the end of both 1 and 24 hours, using a Riehle compression testing machine with a range of 1,000 pounds and a head speed of 0.003 inch per minute.

RESULTS

The strength at the end of 1 hour after condensation is shown in Table I, together with the percentage reduction in strength resulting from a reduction in condensation force. A force greater than 8 to 10 pounds on a 2 mm. diameter hand

*Baker Aristaloy; Caulk Twentieth Century: fine cut, micro nonzinc, and regular cut; S. S. White: New True Dentalloy, True Dentalloy—Sigrens, and zinc-free True Dentalloy.

TABLE I. EFFECT OF CONDENSATION FORCE ON COMPRESSIVE STRENGTH OF DENTAL AMALGAM AT END OF 1 HOUR

ALLOY	COMPRESSIVE STRENGTH AT 1 HOUR (P.S.I.)						
	8–10 POUNDS*	6–8 POUNDS*	REDUCTION (%)†	4–6 POUNDS*	REDUCTION (%)†	2–4 POUNDS*	REDUCTION (%)†
A (regular)	12,700	10,200	20	9,600	24	8,100	36
B (fine)	13,200	10,600	20	9,500	28	8,600	34
C (fine)	13,500	12,800	5	12,200	9	10,600	21
D (no zinc) (fine)	5,800	5,200	10	5,000	14	4,900	15
E (fine)	6,700	6,000	14	5,000	25	3,500	48
F (no zinc)	11,800	10,900	7	10,200	13	9,800	16
G (regular)	10,100	9,500	5	8,100	20	7,600	24

*Round hand condenser with 2 mm. diameter.
†From values obtained with 8 to 10 pounds of condensation.

condenser was not used in this study, since it is considered that greater force applications are impractical in clinical practice.

From Table I, it can be seen that at the end of 1 hour after condensation, the strength of the seven products varies from 5,800 to 13,500 p.s.i. It can be seen also that two of the seven products (D and E) have characteristically lower strength values at the end of 1 hour when condensed with 8 to 10 pounds than the remaining five products. Product D represents an alloy without zinc, while alloy E contains zinc, and both alloys have a fine particle size. All products show a significant reduction in strength with a reduction in condensation force from 8 to 10 pounds to 2 to 4 pounds. As can be seen from Table I, the strength values range from 3,500 to 10,600 p.s.i. with 2 to 4 pounds of condensation force. This represents a percentage reduction, from the 8 to 10 pounds condensation values, ranging from 15 to 48 per cent for the different products. No significant pattern of strength reduction related to force of condensation is evident from Table I. For example, the three products (A, B, and C) representing the highest strength values when well condensed (8 to 10 pounds) show from 20 to 35 per cent reduction in strength when condensed with low forces (2 to 4 pounds). Two of these three alloys are described as fine cut, and one is regular in particle size. The two products with the lowest strength values (D and E) show 15 and 48 per cent reduction in strength, respectively, when condensed with low forces. One was free from zinc (D) and the other contained zinc, but both represented fine cut products.

At the end of 24 hours, as shown in Table II, the strength of all products ranged from 32,800 to 42,000 p.s.i. when condensed with a force of 8 to 10 pounds. This represents a 22.3 per cent difference in strength between the strongest and weakest alloys, both of which (C and E) represent alloys containing zinc and described as fine cut products. Actually, these were the two with the finest particle size of the seven alloys studied. The remaining five alloys had strength values of from 35,100 to 40,600 p.s.i., representing approximately 13 per cent maximum

TABLE II. INFLUENCE OF CONDENSATION FORCE ON COMPRESSIVE STRENGTH OF DENTAL AMALGAM AT END OF 24 HOURS

ALLOY	COMPRESSIVE STRENGTH AT 24 HOURS (P.S.I.)						
	8–10 POUNDS*	6–8 POUNDS*	REDUCTION (%)†	4–6 POUNDS*	REDUCTION (%)†	2–4 POUNDS*	REDUCTION (%)†
A	35,400	33,900	4	33,900	4	30,800	13
B	40,300	37,400	7	36,500	9	34,800	14
C	42,000	41,400	1	38,600	8	37,800	10
D	35,100	35,000	0	34,800	1	34,300	2
E	32,800	32,300	1	31,500	4	31,200	5
F	38,600	37,400	3	36,700	5	35,000	9
G	40,600	40,000	1	39,600	2	37,000	8

*Round hand condenser with 2 mm. diameter.
†From values obtained with 8 to 10 pounds of condensation.

difference in strength when well condensed (8 to 10 pounds), and these include alloys with regular and fine cut particles as well as alloys with and without zinc present.

A reduction in condensation force to 2 to 4 pounds caused a reduction in strength of the amalgam at the end of 24 hours, as can be seen from Table II. The percentage reduction for all products is appreciably less in the 24 hour tests than at the end of 1 hour. It can be observed that the range in percentage reduction is from 2 to 14 per cent (D and B). The three products (A, B, and C) having the greatest strength after both 1 and 24 hours when well condensed (8 to 10 pounds) showed the greatest percentage reduction in strength (10 to 14 per cent) with a reduction in condensation (2 to 4 pounds) after 24 hours. In contrast, the two alloys (D and E) having the lowest strength after both 1 and 24 hours when well condensed showed the lowest percentage reduction in strength (2 to 5 per cent) with a reduction in condensation of from 2 to 4 pounds.

The difference between the strongest and weakest products (A and C) after 24 hours with a light condensation force (2 to 4 pounds) is 7,000 p.s.i., or 18.5 per cent, which is less than the difference (22.3 per cent) between the strongest and weakest products (C and E) when well condensed, as indicated above. A comparison of the strongest alloy when well condensed (C) with the weakest alloy (A) when less well condensed (2 to 4 pounds) after 24 hours shows a difference of 26.6 per cent between the two, which represents the maximum difference to be expected among the various products as they are influenced by forces of condensation. Thus, it can be seen that as much difference can result from poor condensation of high strength products as exists between available products.

MERCURY CONTENT

The compressive strength samples used for the 24 hour tests were analyzed for mercury content to determine any relationship of strength properties to the

quantity of mercury present in the amalgam. Analysis was not made of the 1 hour samples since they were prepared under the same conditions of condensation as the 24 hour compression samples. The mercury was determined by the method suggested by Hillenbrand and Lundell,[8] which involves the collection of the mercury distilled from the amalgam mass, with subsequent volumetric titration with thiocyanate, which is accepted to be accurate to 0.02 per cent.

Results of the mercury analysis are shown in Table III, together with the corresponding compressive strength values for each alloy when condensed with different applied forces. The strength values are recorded to the nearest 10 p.s.i. rather than to the nearest 100 p.s.i. as given in Table II. This was done to indicate the relationship that appears to exist between small variations in both mercury content and strength values of some samples, as for example alloy A condensed with 6 to 8 and 4 to 6 pounds, which otherwise would not become evident.

TABLE III. INFLUENCE OF CONDENSATION FORCE ON COMPRESSIVE STRENGTH AND MERCURY CONTENT OF AMALGAM AFTER 24 HOURS

ALLOY	COMPRESSIVE STRENGTH (P.S.I.) AND MERCURY CONTENT							
	8–10 POUNDS*	MERCURY (%)	6–8 POUNDS*	MERCURY (%)	4–6 POUNDS*	MERCURY (%)	2–4 POUNDS*	MERCURY (%)
A	35,380	45.36	33,940	47.92	33,880	47.62	30,840	49.43
B	40,270	43.74	37,360	43.16	35,460	46.52	34,820	46.98
C	42,020	42.47	41,380	44.30	38,600	44.87	37,820	44.72
D	35,080	44.08	35,040	46.88	34,800	45.04	34,260	45.58
E	32,800	48.39	32,300	48.88	31,520	53.29	31,180	51.47
F	38,600	44.32	37,420	47.13	36,720	47.12	34,960	47.27
G	40,620	42.98	39,960	44.99	39,580	45.75	36,960	47.95

*Round hand condenser with 2 mm. diameter.

Generally, the values in Table III, with one or two exceptions, show an increase in mercury content with a reduction in condensation force, as has been observed by other investigators. The exceptions, with alloys D and E for example, are most apparent in the lower ranges of force of condensation (4 to 6 and 2 to 4 pounds) and may be related to the fact that values for both strength and mercury content are values representing averages of several test samples as well as possible lack of homogeneity in the test samples when condensed at the lower forces. The fact that the condensation forces represent a range of values lends emphasis to the desirability of comparing primarily only the values in the upper range of condensation forces with those in the lower ranges, to indicate trends that exist rather than suggest absolute values for all results and test conditions reported.

From Table III it can be seen that when amalgam is well condensed (8 to 10 pounds), the maximum difference in both strength and mercury content is represented by alloys C and E, suggesting a correlation between mercury content and strength. All other alloys have strength and mercury content values between the

limits established by these two. The strength of alloy C is seen to be 9,220 p.s.i. greater than that of alloy E, and alloy C contains 5.92 per cent less mercury. Why this condition exists is not evident from this study, but it is suggested that it may be related to the silver : tin ratio in the alloy, the heat treatment of the alloy, the mercury : alloy ratio used, or other such factors, since both alloys contain zinc, are extremely fine cut, and were condensed under the same conditions.

When low forces of condensation (2 to 4 pounds) are employed, it can be seen from Table III that alloys C and E continue to represent the strongest and the weakest of the alloys studied and also have the greatest difference in mercury content. The difference in strength is 6,640 p.s.i., while the mercury content differs by 6.75 per cent between these two alloys.

The increase in mercury content of the amalgam varies appreciably with different alloys from the well-condensed mass (8 to 10 pounds) to those with low condensation forces (2 to 4 pounds), as shown in Table III. The greatest increase in mercury content with reduction in condensation force was shown by two of the regular particle size, zinc-containing alloys, A and G, which showed 4.07 and 4.97 per cent, respectively, more mercury with low condensation forces. The least influence of condensation force on mercury content was shown by alloys C (2.25 per cent) and D (1.50 per cent), both of which were fine cut and one of which (D) did not contain zinc. It is interesting to observe that alloy D represented the minimum percentage variation in strength (Table II) as a result of reduction in condensation force and also showed the least variation in mercury content.

This variation in strength and mercury content, as influenced by condensation forces, possibly is of little consequence in relation to particle size, the presence of zinc in the alloy, or relations to the fundamental strength of the amalgam, since product C, a fine cut, zinc-containing alloy, and product G, which is a regular cut zinc-containing alloy, have the greatest strength and lowest mercury content of any products when well condensed (8 to 10 pounds) and also show the greatest strength with low condensation forces (2 to 4 pounds), but only alloy C continues to have the lowest mercury content. This suggests that other factors, such as composition or heat treatment may be important in controlling the mercury content of the alloy, both fundamentally and when the condensation forces are varied. All products showed less than 50 per cent mercury in the amalgam when well condensed, and two contained less than 43 per cent.

DISCUSSION

Several observations of practical significance are apparent from this study. Tests were made with amalgam alloys produced by three reputable manufacturers, and the alloys are recognized as being suitable for serviceable clinical restorations. In spite of the clinical acceptance of all the alloys studied, there were differences observed in the strength developed by the amalgam produced from the several alloys. It was observed that well-condensed amalgam from the seven alloys may vary after 24 hours as much as 9,200 p.s.i. from one product to another. This means that the weaker product is only about 80 per cent as strong as the strongest one. Greater differences exist in the strength of different products at the end of

1 hour, even though the amalgam is well condensed. The full practical significance of such observations is not known because of the apparent clinical acceptability of each product. Certainly, it can be reasoned that weaker alloys are not to be considered superior to the stronger products. It may be reasoned, however, for years of serviceability, it is perhaps more important that the final strength be at a maximum than to give overemphasis to the potential development of a high percentage of the final strength shortly after condensation. In these studies, alloy A, which is a zinc-containing, regular particle size alloy, had a strength of more than 12,000 p.s.i. at the end of 1 hour, while product D, a fine cut product without zinc had a strength of approximately 6,000 p.s.i. When well condensed, these same two alloys had approximately the same strength at the end of 24 hours, and with a low force of condensation, amalgam A had less strength than amalgam D. If protected by the patient for a short time (6 to 8 hours) in the early stages after condensation, it is presumed that either product would be serviceable.

The importance of adequate force applications during condensation are shown to be related to the strength developed in the amalgam mass. Well-condensed amalgam specimens such as alloys B, D, and F after 24 hours show appreciable differences in strength, but if the amalgam is not well-condensed, the three products have approximately the same strength values. The poor condensation practice reduced the strength of product D only 2 per cent, but product B was reduced 14 per cent as a result of the variation in manipulation. The early strength of the amalgam as indicated by the 1 hour tests is reduced even more than the final strength by reduction in the condensation force on the amalgam. These studies support the belief that the maximum strength in amalgam is developed only when the mass is well condensed with a maximum practical force applied.

The results from this study do not indicate that the particle size of the alloy, or the presence of zinc, is the principle controlling factor in the development of maximum strength in the amalgam, either after 1 hour or at the end of a 24 hour period. The mercury content of amalgam produced from the seven alloys studied showed that differences exist in the amount of mercury retained by different alloys. In general, the lower the mercury content of the amalgam, the stronger it is, and the greater the force of condensation, within the range of this study, the less is the amount of mercury retained by the amalgam. No evidence was found to suggest that the mercury content of all alloys can be made to be the same with the same forces of condensation applied to the different products. No evidence was observed from this study to indicate that amalgam samples with low mercury content tend to develop their maximum strength faster than those with increased mercury content.

From this study, it is apparent that seven dental amalgam alloys, recognized as producing clinically serviceable restorations, do possess different values for compressive strength. Some develop their strength more rapidly than others, and some tend to retain more mercury after condensation. The strength of all alloys is altered by the force of condensation, which is directly related to the mercury content of the condensed amalgam but not to the same degree for all products. A potentially strong amalgam may be weaker as a result of poor condensation practices than an amalgam which is well condensed from an inherently weaker

alloy. The alloys studied showed smaller percentage variation in strength after 24 hours than in the early periods after condensation. This study does not support the proposal that all products described as having fine cut particles always have superior compressive strength values.

CONCLUSIONS

1. The compressive strength of well-condensed amalgam after 24 hours may vary from one product to another by more than 20 per cent.

2. Amalgam that is of potentially high strength when well condensed may show a loss of more than 10 per cent of its strength when poorly condensed.

3. The reduction in strength resulting from low force of condensation is more significant after 1 hour than after 24 hours.

4. A claim that an amalgam alloy is made of fine particles is no assurance that the amalgam will have a high compressive strength even when well condensed.

5. A low mercury content in the amalgam is associated with high compressive strength values, and both result from the use of high condensation forces, even though values will vary from one product to another.

6. When well condensed, an amalgam with low mercury content does not necessarily develop its maximum strength faster than one with a higher mercury content.

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BOND STRENGTH OF REPAIRED AMALGAM

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WHEN AN AMALGAM RESTORATION requires attention because of fracture, poor marginal adaptation, recurrent caries, or other reasons, it is often repaired, rather than replaced, by the condensation of a new mix of amalgam against part of the existing restoration. For example, an MOD restoration may be faulty on the mesial surface; the dentist replaces only the mesio-occlusal section and creates a bond of old to fresh amalgam somewhere on the occlusal surface. Or, following the insertion of a new amalgam restoration, various accidents may cause small fractures which are repaired immediately with a new mix of amalgam, thereby creating another type of bonding condition.

The purpose of this investigation was to determine the strength of amalgam bonds under various conditions by means of a transverse bend test.

PROJECT PLAN

Since amalgam failures are characteristically a result of tensile and/or shear stresses, a test involving these stresses would be most valid in determining the integrity of the bond in a repaired amalgam restoration. Therefore, a transverse bend test (three point loading) was selected as the technique of evaluation.

The test samples were prepared in a rectangular steel mold under clinical conditions of amalgam manipulation. After aging, each sample was fractured in half under transverse loading, and the transverse strength was determined. One of the fractured halves was trimmed and reinserted into the mold, and a new mix of amalgam was consensed against it. The transverse strength was determined for the repaired sample and compared to the transverse strength of the original sample.

In addition to determining the strength of amalgam bonds made in accordance with presently accepted techniques, several other factors were evaluated for their respective influences on bond strength: (1) the age of the amalgam sample at the time of its repair, (2) the mercury:alloy ratio of the initial increments condensed against the older sample, and (3) the direction of condensation.

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METHOD OF TEST

Sample Preparation.—The amalgam alloy* was used at a mercury:alloy ratio of 7:5 as prescribed by the manufacturer. The mercury and alloy proportions were measured using an S. S. White mercury dispenser and a Crandall balance, respectively. Trituration of a 0.78 Gm. mix was conducted in an S. S. White amalgamator for 20 seconds without a pestle. Excess mercury was expressed through a squeeze cloth in keeping with routine clinical procedure.

The amalgam was hand condensed into a steel mold to produce a rectangular sample measuring 1 mm. thick, 4 mm. wide, and 12 mm. long. The top section of the mold was removable so that the sample could be carved down uniformly to remove the last mercury rich, poorly condensed portion. The condenser used was an American No. 13 having a rectangular face which measured 0.06 by 0.03 inch. A condensation force of approximately 6 pounds was used, thereby producing a condensation stress of 3,350 p.s.i. A disassembled view of the mold is shown in Fig. 1 and an assembled view in Fig. 2 together with the condenser used and a finished amalgam test sample.

The sample was condensed in 3 minutes from the start of trituration, the upper part of the mold was removed at 5 minutes, the sample was carved at 5½ minutes, and the sample was removed at 6 minutes.

All samples were stored at laboratory conditions of temperature and humidity.

Test Procedure.—After 7 days, the samples were placed in the transverse test apparatus. In this specially designed apparatus, the sample rests on two parallel rods, 10 mm. apart, and load is applied to the top of the sample at the center. The load was applied by a transducer load beam the signal from which was sent to a recorder. The recording indicated the load to an accuracy of ± 0.1 pound. A photograph of a close-up view of the test sample in the apparatus is shown in Fig. 3. The samples were loaded, and the load at the fracture point was converted to transverse strength by the following formula:

$$S_T = \frac{3WL}{2bh^2}$$

where W = fracture load
L = sample length between supports (10 mm.)
b = sample width (4 mm.)
h = sample thickness (1 mm.)

The sample dimensions indicated are approximate, and for actual computation, the samples were measured with a micrometer to the nearest 0.0001 inch. Loading was conducted at a rate of 0.05 inch per minute.

After the 7 day transverse strength of the base samples was determined, the fractured ends of the longer pieces were "freshened" with a No. 559 plain fissure bur in a straight handpiece using a mechanical apparatus to ensure precise and careful cutting. Each sample was trimmed to 6 mm. and replaced in the mold. A new mix of amalgam was condensed against the freshened half, thereby producing a new sample with the bond between old and new amalgam located at the center

*S. S. White New True Dentalloy, Batch 14060118.

of the sample. After 7 days, the repaired amalgam samples were fractured by the method described, the transverse strength was determined, and the resulting figures were compared to the 7 day strength of the original base samples.

Age of Amalgam at the Time of Fracture and Repair.—The influence of the age of the repaired amalgam on the strength of the bond was determined at two times which were selected because of their clinical significance: (1) The original sample was fractured at 7 days and repaired immediately with a new mix of amalgam. This type of bonding is comparable to that produced by the repair of a silver amalgam restoration which has been in service. (2) The original sample was trimmed with a bur at 10 minutes of age and repaired at 15 minutes with a new mix of amalgam. This was considered representative of the type of bonding which

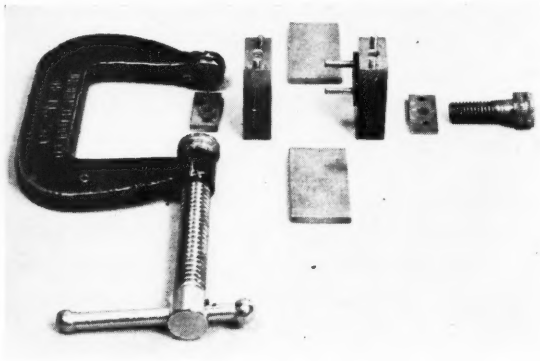

Fig. 1.—Disassembled view of the steel mold used in forming the transverse strength samples.

may occur when a fresh amalgam resoration is repaired because of an accidental fracture during carving, removal of the matrix band, or inadvertent closing by the patient before high areas are relieved.

Mercury:Alloy Ratio of Initial Repair Increment.—It was hypothesized that the strength of the bond might be influenced by the amount of mercury present at the surface to be bonded during the time of repair. Hence, the previous procedures were repeated with two new series of samples, one which utilized a 58.3 per cent mercury rich initial increment of amalgam against the trimmed surface and another with a 70 per cent mercury rich initial increment. In each case, the mold was filled with subsequent increments of amalgam, proportioned at a 7:5 ratio, and squeezed dry, according to clinical procedures.

Amalgam Repaired With the Same Mix.—After these tests were conducted, a question arose as to whether the strength of the bond was influenced by the fact that the new amalgam was being condensed against a surface which was already well condensed. This condition is different than that which exists during normal procedures where each increment is condensed against a mercury rich surface having a high potential for crystal growth. To evaluate this factor, a metal spacer was placed in one half of the mold, and amalgam was condensed into the open half in

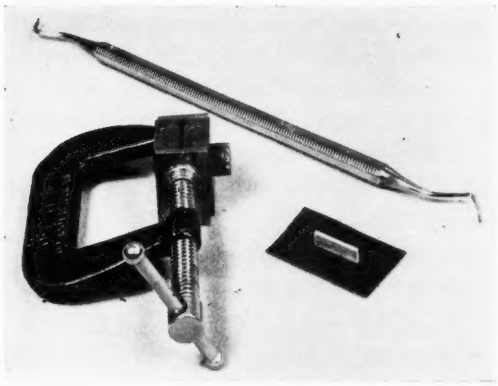

Fig. 2.—Assembled view of the steel mold used in forming the transverse strength samples.

1 minute. The spacer was removed quickly, and the second half was condensed with the remainder of the initial mix to complete the sample. Two conditions of condensation were evaluated: the second half was condensed parallel to the first half and perpendicular to the first half.

RESULTS AND DISCUSSION

The results of this investigation are shown in Fig. 4. The strength of the bond was taken to be the computed transverse strength of the test samples with the repaired bond directly below the application of load at the center of the sample, which is the point of maximum tensile stress. In each instance, the sample broke at the bond. The height of each bar represents the arithmetic mean of twenty test runs for each condition. The standard deviations were of the order of 1,200 p.s.i., with the exception of the 15 minute repair with no surface treatment, which had a standard deviation of 1,760 p.s.i. Means were compared by the *t* test at the 95 per cent level of confidence.

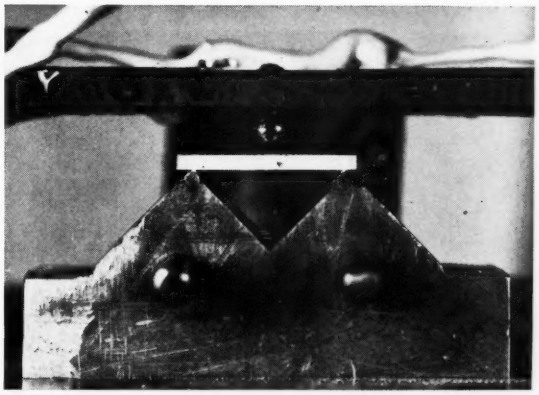

Fig. 3.—Close-up of a sample in the transverse strength apparatus (three point loading).

The transverse strength of the original unrepaired sample, called the base sample, was 20,600 p.s.i. and is drawn as the first bar on the graph. The optimal repair condition, therefore, should exhibit a strength of the order of magnitude of this base sample. As can be seen, all of the repair conditions tested produced strength of less than one-half the strength of the original amalgam, and the highest strength of a repair condition was 8,700 p.s.i., which is about 42 per cent of the strength of the original amalgam.

It can be seen that the amalgam repaired at 15 minutes exhibited up to 50 per cent greater strength than amalgam repaired at 7 days.

In the case of the 15 minute repair, when the surface to be bonded was treated with an increment of mercury rich amalgam, the strength of the bond was increased, but no improvement was achieved in going from a 58.3 per cent mercury content increment to a 70 per cent mercury content increment.

In the case of the 7 day repair, little or no improvement was demonstrated in using an increment of mercury rich amalgam.

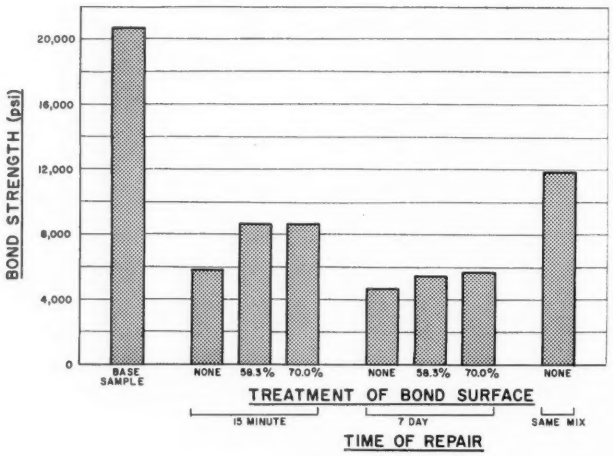

Fig. 4.—Bond strength of repaired amalgam under various conditions of repair.

As a result of these tests, it was hypothesized that the low bond strength of amalgam may result from the fact that the amalgam to be repaired offers little contribution to crystal growth across the bonding surface and any bonding which does exist emanates from the newly mixed amalgam. This lack of potential for outward crystal growth on the part of the old amalgam may be due to two factors: (1) the amalgam being partially or completely set or (2) the amalgam being compacted by previous condensation at the repair surface. To determine whether one or both of these factors might be significant, a test was conducted which eliminated one of them, namely, the condition of the amalgam being set. The conditions for this test were to place a spacer in the mold, condense one half of the sample, remove the spacer, and condense the second half using the remaining portion of the original mix of amalgam. The entire condensation was completed in the same time used for

the base sample. The result of this test is represented by the last bar on the graph (Fig. 4). As can be seen, the strength is reduced to 11,900 p.s.i. compared to 20,600 p.s.i. for the base sample. The fact that the bond surface is compacted is evidently a major factor in the inability of an amalgam repair to approximate the strength of the original amalgam. It would appear that this value of 11,900 p.s.i. represents a limit which any repair condition would have little chance of exceeding. In addition, the fact that the strength values of the samples repaired at 15 minutes and 7 days were less than the condition using the very same mix for repair demonstrates that the setting progress of the amalgam is also a deterrent to optimal bond strength.

All of these repairs were made with the new amalgam condensed parallelly to the bond surface. The results of a test with the new amalgam condensed perpendicularly to the bond surface showed no statistical difference in bond strength when compared to parallel condensation and were therefore not represented in Fig. 4.

SUMMARY AND CONCLUSIONS

In this study, the strength of the bond of repaired amalgam with the use of hand condensation techniques was investigated. Several conclusions appear to be indicated.

1. The bond strength of repaired amalgam is less than one-half the strength of unrepaired amalgam.

2. The bond strength of amalgam repaired at 15 minutes is approximately 50 per cent stronger than that of amalgam repaired at 7 days.

3. A mercury rich increment at the repair surface increases the strength of the bond when amalgam is repaired at 15 minutes but offers little benefit when amalgam is repaired at 7 days.

4. A possible hypothesis for the low strength of a repaired amalgam is lack of potential for crystal growth on the part of the old amalgam. This lack of potential is due to compaction of the amalgam at the repair surface as well as the fact that the amalgam is partially or completely set.

These results support the clinical implication that the repair of fractured amalgam is a hazardous procedure from a strength standpoint. It is possible that if the repair is done in an area of low tensile stress or if mechanical locking by undercutting and dovetailing is used, this hazard of low strength may be mitigated. However, in either case, the bond is a source of weakness, and factors such as tarnish, corrosion, and leakage at the bond surface may still present formidable barriers to the integrity of the repaired structure.

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INDIRECT TECHNIQUE FOR MAKING PORCELAIN INLAYS

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THE PORCELAIN INLAY has long been credited with possessing unsurpassed qualities for the restoration of anterior teeth.[1-7] However, the procedures necessary to produce these qualities were so demanding that their use was confined to a small segment of the profession. Such limitations can now be reduced to a minimum by utilizing a new refractory investment.† This investment, vibrated into a rubber or silicone impression of the cavity, produces a mold in which porcelain can be fired directly.

In 1894 Herbst,[8] of Germany, attempted to fire porcelain inlays in a plaster of Paris mold. Through the ensuing years, a number of techniques making use of refractory investments have been described.[9-18] However, the platinum matrix technique is still the popular one.

It is our opinion that with the following technique, the average dentist should encounter little difficulty in constructing well-condensed, accurately fitting porcelain inlays.

SHADE SELECTION

Prior to beginning cavity preparation for any porcelain restoration, careful attention should be given to shade selection. If it is possible to make a tentative selection of the shade at some earlier appointment, the dentist will have the advantage of confirming or modifying his choice.

CAVITY PREPARATION

Two features are necessary to provide adequate retentive form in porcelain inlay cavities: (1) the depth of these preparations must be slightly greater than for either gold foil or gold inlays and (2) the retentive walls of these cavities should be only slightly divergent (Fig. 1).

The nature of porcelain makes it advisable to avoid sharp angles in the outline form (Fig. 1). However, the cavosurface *must* be sharp, true, and without bevels.

Of particular importance is the fact that the dentist has greater freedom in the selection of cavity form, since the need for adaptation of a platinum matrix is eliminated and because elastic impression materials are used.

---

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†Myken porcelain inlay investment.

Fig. 1

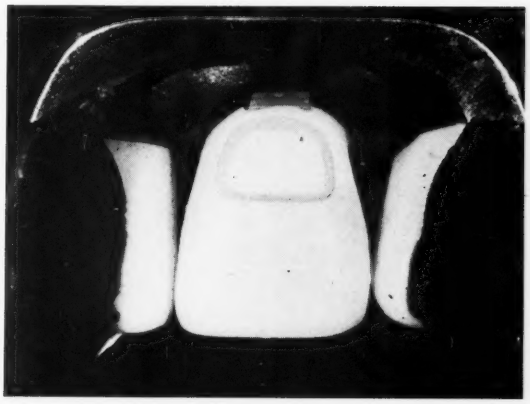


Fig. 2

Fig. 1.—A class V porcelain inlay preparation on an upper central incisor.
Fig. 2.—The completed preparation in a dry operating field.

Fig. 3

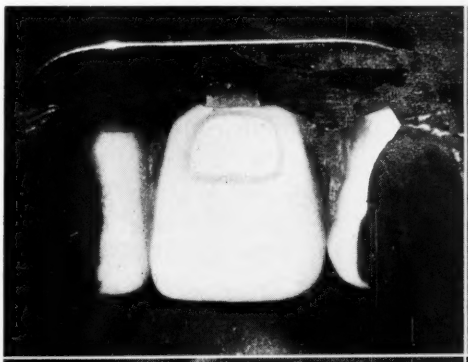
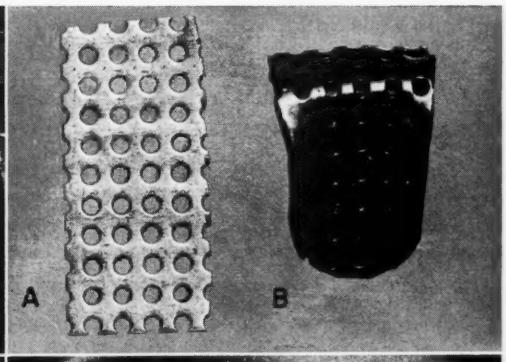


Fig. 4



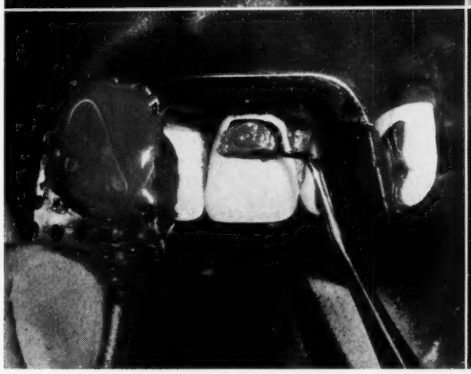


Fig. 5

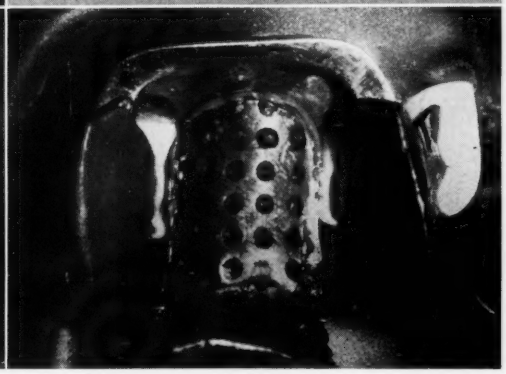


Fig. 6

Fig. 3.—The interproximal spaces and labial jaw of the gingival clamp are blocked out with soft wax.
Fig. 4.—*(A)* Perforated metal tray material; *(B)* A contoured tray with an adhesive applied.
Fig. 5.—Polysulfide rubber impression material is applied to the cavity preparation with a small instrument, and the tray is loaded with a small amount of the impression material.
Fig. 6.—The impression is allowed to set for 8 to 10 minutes.

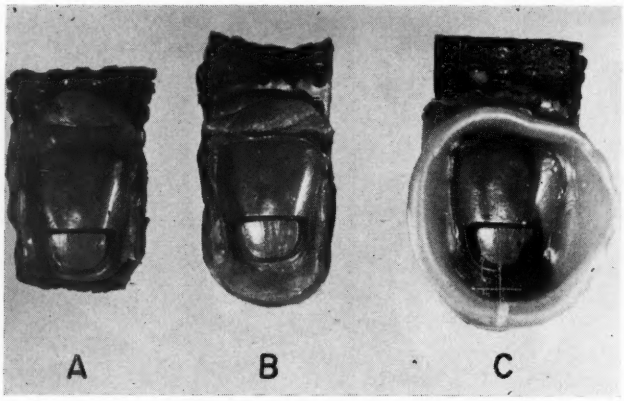


Fig. 7.—*(A)* The excess rubber-base material is trimmed from the impression; *(B)* undercuts caused by the gingival clamp are filled with soft wax; *(C)* the impression is boxed with a strip of wax.

The best operating field is attained by the use of a rubber dam. For class V preparations, a No. 212 gingival clamp will provide adequate tissue retraction (Fig. 2). A separator may be necessary for some class III cavities.

Details of instrumentation and various cavity forms are not pertinent to this discussion. However, this subject is important and will be dealt with at a later date.

IMPRESSIONS

Rubber-base or silicone materials are the impression materials of choice for this technique.

The interproximal spaces and the labial jaw of the clamp are blocked out with soft wax to prevent locking of the impression material (Fig. 3). In class III cavities

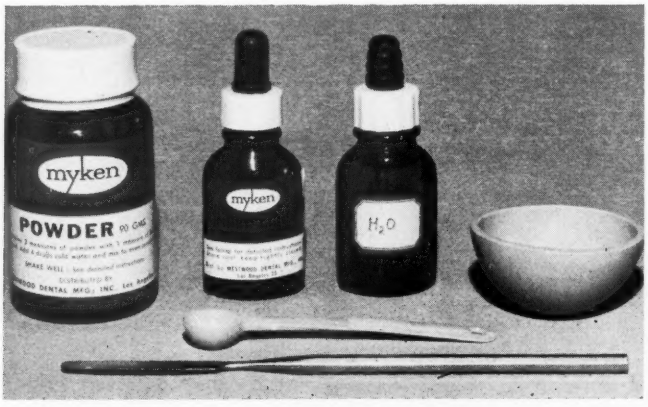


Fig. 8.—The armamentarium necessary for mixing and pouring the investment mold includes a small rubber bowl, cement spatula, vibrator, measuring spoon, investment powder, investment binder liquid, and water dropper bottle.

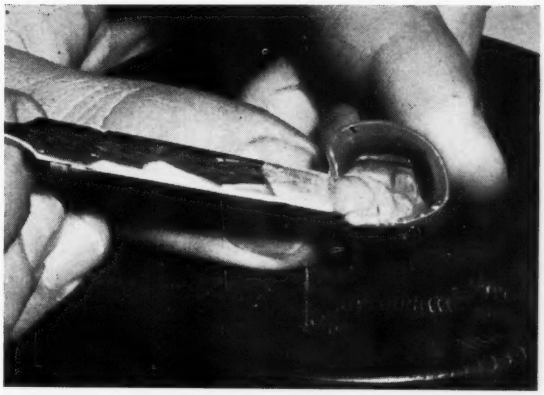


Fig. 9.—The investment is vibrated into the boxed impression.

with a labial draw, soft wax is adapted on the lingual surface to within 0.5 mm. of the cavity. This will limit the lingual flow of the impression material that might otherwise cause distortion. In cavities with a lingual draw, the wax is similarly placed on the labial surface. A strip of perforated metal is trimmed to the approximate width of the tooth. The metal is then contoured and coated with adhesive (Fig. 4).

The impression material is carefully applied to the cavity with a small instrument (Fig. 5). The tray is loaded, placed in position, and left for 8 to 10 minutes (Fig. 6). When pinholes are involved, a fine instrument is used to work the impression material to their depth.

After removal of the impression, excess material is trimmed from the tray (Fig. 7, *A*). Undercuts or voids close to the cavosurface margin are filled with wax (Fig. 7, *B*). This prevents possible fracture of the investment mold upon sep-

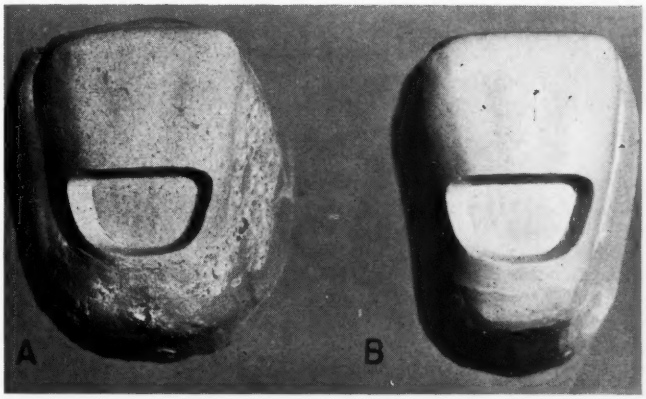


Fig. 10.—*(A)* The refractory investment mold is separated from the impression; *(B)* a second pour of the impression in a hard die stone, to serve as a trial die.

Fig. 11

Fig. 14

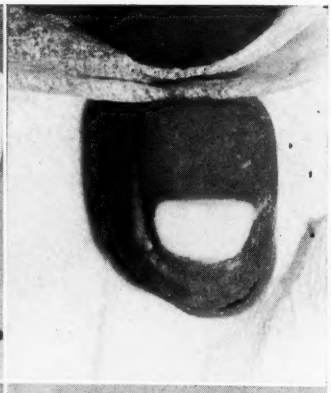


Fig. 12

Fig. 15

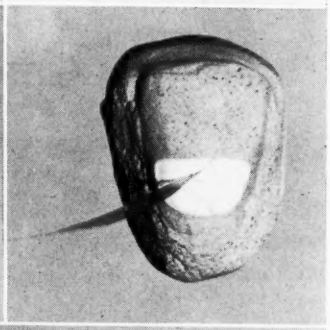


Fig. 13

Fig. 16

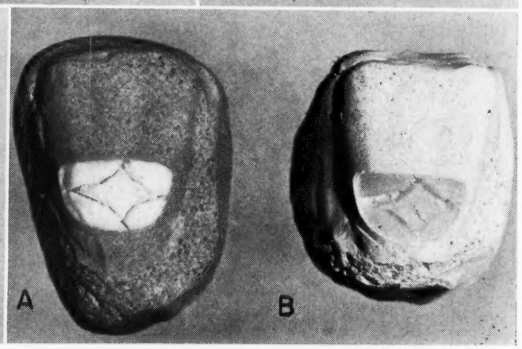


Fig. 11.—The armamentarium necessary for application of porcelain includes a porcelain carver, small brush, medium brush, thin scoring blade, porcelain, water dropper bottle, dappen dish, tissue, and sagger tray.

Fig. 12.—The investment mold is saturated with water.

Fig. 13.—The first application of porcelain into the investment mold is made with a porcelain carver.

Fig. 14.—Condensation of porcelain is accomplished by the removal of water from the bottom of the mold with tissue.

Fig. 15.—The porcelain is scored to control the direction of shrinkage during firing.

Fig. 16.—First application of porcelain: *(A)* before firing; *(B)* after firing.

aration. The impression is boxed with a strip of wax approximately ¾ inch wide to provide a substantial base for ease of handling (Fig. 7, *C*). Impressions of some class III cavities may not lend themselves to boxing. In such a situation, an adequate base can be formed or shaped with the fingers.

POURING THE INVESTMENT MOLD AND TRIAL STONE DIE

The investment, mixed in accordance with instructions (Fig. 8), is carefully vibrated into the impression (Fig. 9). It is allowed to set for approximately 20 minutes and then is gently separated in the direction of the draw of the cavity (Fig. 10, *A*). Several molds may be poured from one impression if desired.

A hard die stone is then poured into the impression. This provides a trial model in which the porcelain inlay is fitted before placement in the mouth (Fig. 10, *B*).

The investment mold is allowed to dry at room temperature for 5 minutes and then is preheated in front of the open porcelain oven for 5 minutes. It is then heated to 2,000° F. in the oven and removed. When cool, the investment mold is ready for the application of porcelain.

Fig. 17 Fig. 18 Fig. 19

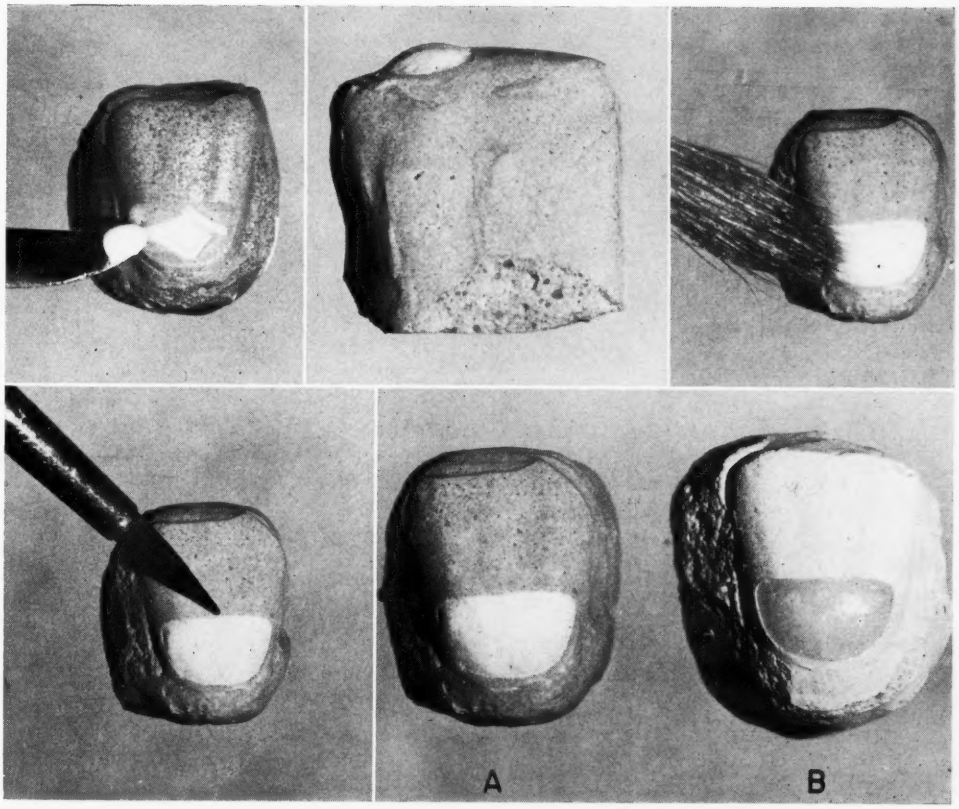


Fig. 20 Fig. 21

Fig. 17.—The second application of porcelain, filling the voids resulting from shrinkage.
Fig. 18.—A lateral view of the second application of porcelain showing the overcontouring.
Fig. 19.—The porcelain is smoothed with a medium size brush.
Fig. 20.—A small, moistened brush is used to remove any porcelain extending past the cavosurface of the mold.
Fig. 21.—The second application of porcelain: *(A)* before firing; *(B)* after firing.

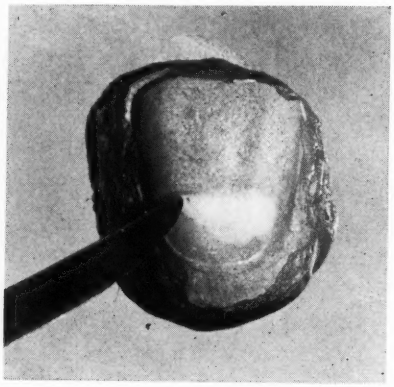


Fig. 22.—The third application of porcelain is made to correct any deficiencies at the margins or in contour.

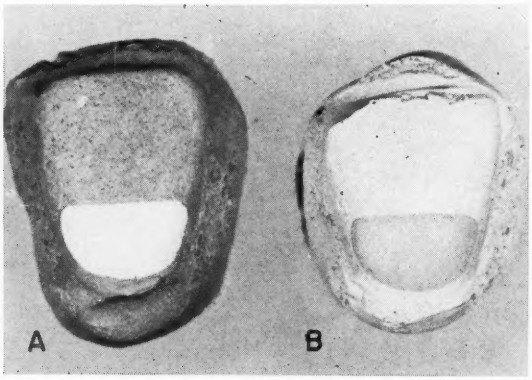
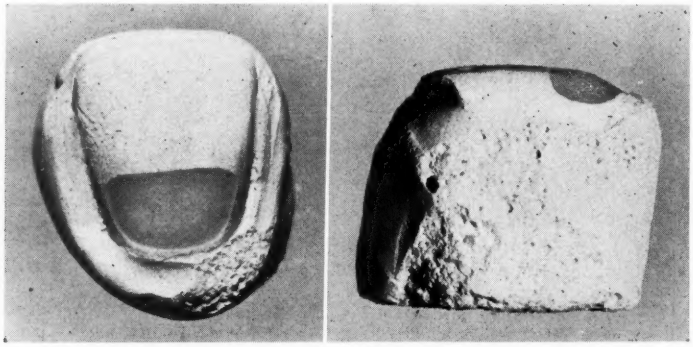


Fig. 23.—The third application of porcelain: *(A)* before firing; *(B)* after firing.



A. *B.*

Fig. 24.—The porcelain is glazed. *A,* Labial view. *B,* Lateral view.

APPLICATION AND FIRING OF PORCELAIN

Porcelain that is low or medium fusing may be used, depending on personal preference. However, a low-fusing porcelain is recommended because of the rapidity of the firing procedure (Fig. 11). Usually, three or four applications of porcelain are necessary in order to obtain the desired contour and marginal integrity.

The mold is saturated with water (Fig. 12), and fluid porcelain is applied with a porcelain carver (Fig. 13). Excess water is drawn from the porcelain by holding tissue to the bottom or sides of the mold (Fig. 14). This brings about good condensation without the need for vibration. If the porcelain does not flow when applied, more water should be added to the mold. The cavity should be filled just short of the cavosurface and the porcelain scored with a sharp thin blade (Fig. 15). The mold is preheated, and the porcelain is fired to a medium biscuit (Fig. 16).

Fig. 25 Fig. 26

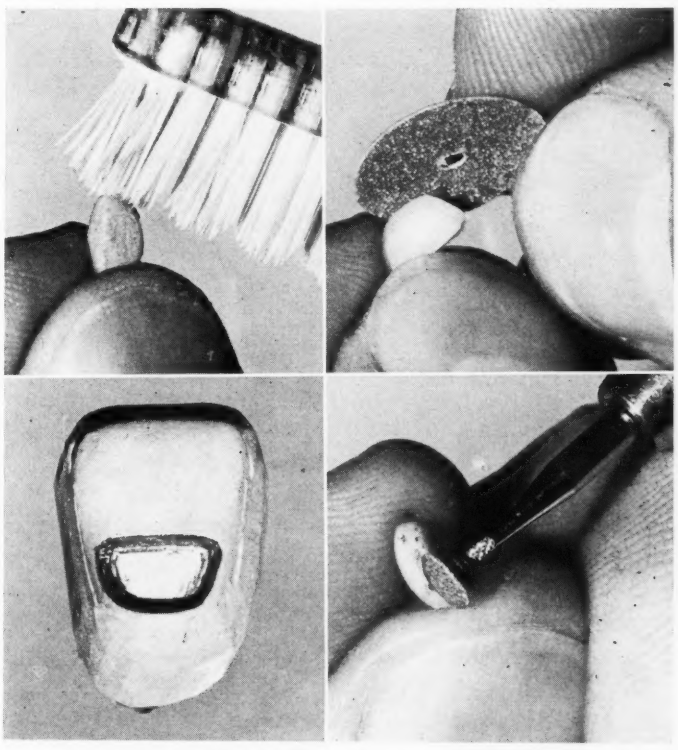


Fig. 27 Fig. 28

Fig. 25.—The investment has been broken away, and the porcelain inlay is scrubbed clean with a wet toothbrush.

Fig. 26.—Small fins of porcelain at the margins are removed with a fine, unmounted garnet disk.

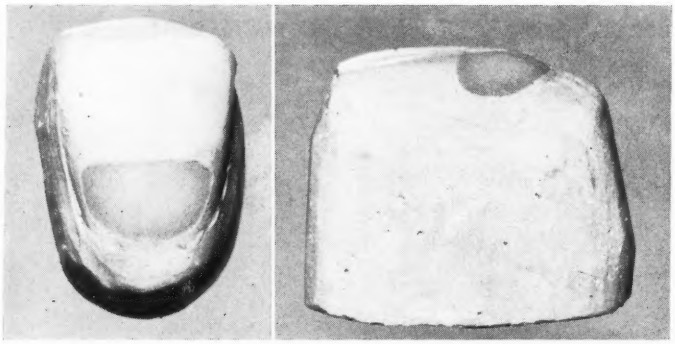
Fig. 27.—A trial stone die with the walls coated with graphite.

Fig. 28.—Any points of interference in the inlay become marked upon insertion into the trial die. These are removed with a small carborundum stone.

The mold is wet thoroughly, then a very fluid porcelain is applied to fill the voids resulting from scoring and shrinkage (Fig. 17). The porcelain is built precisely to the margins and is slightly overcontoured (Fig. 18). This contour may be smoothed with a medium size brush (Fig. 19). A small moistened brush is used to remove any porcelain that may have flowed past the margins (Fig. 20). Instruments *should not* be used for this purpose. The mold is then preheated and fired to a high biscuit (Fig. 21).

A thin layer of fluid porcelain will usually correct any deficiency at the margins or in contour (Fig. 22). If the mold is dried slightly, this porcelain will usually stop at the margins. It is preheated and fired again to a high biscuit (Fig. 23).

If the contour and margins are satisfactory, the inlay may be glazed (Fig. 24).



A. *B.*

Fig. 29.—The porcelain inlay fitted into the trial die. *A*, Labial view. *B*, Lateral view.

PRELIMINARY FITTING IN TRIAL DIE

The investment is broken away and the inlay scrubbed clean with a wet toothbrush (Fig. 25). A fine, unmounted garnet disk is used to rub off small fins of porcelain at the margins (Fig. 26). The walls of the trial stone die are marked with a pencil (Fig. 27), and the inlay is inserted with care. Any discrepancies in the inlay that prevent it from going into place will be marked with the graphite on the die and can be removed with a small carborundum stone (Fig. 28). The axial wall should also be relieved. After the inlay is fitted in the trial model (Fig. 29), it should go into place in the mouth without difficulty.

PREPARATION FOR CEMENTATION

Before placement of the rubber dam, a suitable shade of cement* is selected. This selection is verified by trial cementation using glycerin and water with the cement powder.

The rubber dam and clamp are again placed on the tooth, and the inlay is checked for fit (Fig. 30). Any small marginal excess may be carefully reduced with

*Kryptex.

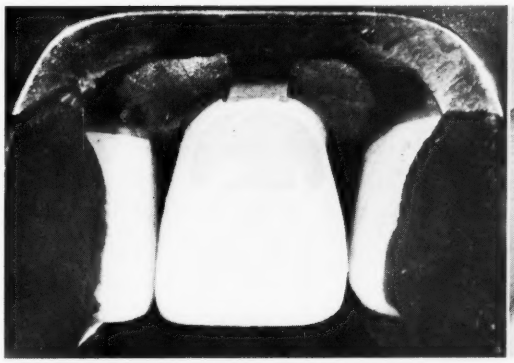


Fig. 30

Fig. 31

Fig. 30.—The porcelain inlay inserted in the preparation.
Fig. 31.—A cement lock is cut in the walls of the inlay prior to cementation.

a fine carborundum stone. The ground surface should be smoothed with a rubber wheel, then polished with a suitable porcelain polish on a wet felt wheel. A small knife edge stone is used to place a cement lock in the walls of the inlay (Fig. 31). Where possible, a similar lock is placed in the cavity walls using a small wheel or inverted cone bur.

The inlay is then cemented in the tooth, and the excess cement is covered with petroleum jelly until the cement has reached its final set. Prior to dismissal of the patient, a cavity varnish is applied to further protect the cement from moisture.

SUMMARY

An indirect porcelain inlay technique has been described whereby a new refractory investment eliminates the need for a rigid die and a platinum matrix. The simplicity of this procedure should place the porcelain inlay within the capability of any dentist who finds a need for this fine restoration in the treatment of his patients.

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ELECTROFORMING A GOLD MATRIX FOR INDIRECT INLAYS

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ELECTROFORMING has been used in dentistry since 1840.[1] The technique has provided a durable die surface of either copper or silver created by electroforming the impression and making a die of the tooth.[2-8] This report describes an electroplating process which forms a gold matrix that has a minimum thickness of 0.005 inch. The matrix is produced on a die of the prepared tooth, and it finally becomes an integral part of the completed casting (Figs. 1 and 2).

CLINICAL USE OF ELECTROFORMED GOLD MATRIX

The electroformed gold matrix makes possible a new and different indirect inlay technique. The dentist makes a rubber-base impression and pours a Densite or Hydrocal die of the tooth in the usual way. The entire surface of the cavity preparation and margins is then metalized by means of a silver paint† to provide a conducting surface[9] on which gold is electrodeposited to the required thickness (0.005 to 0.01 inch). The gold matrix thus formed is returned to the prepared tooth in order to check the accuracy of the matrix and to burnish its margins. This is particularly advantageous in the gingival areas.

The wax pattern is completed within the electroformed gold matrix. A narrow margin of the soft gold matrix is left extending from the wax pattern, which may be safely returned to the tooth for a recheck. The inlay is then completed by casting a suitable gold alloy into the matrix (Figs. 3 and 4). The cast gold forms an intermediate alloy with the pure gold matrix.

For pinlay preparations, gold pins are inserted into the metalized die prior to electroforming.

ELECTRODEPOSITION OF GOLD

Although mainly used for decorative purposes, electrodeposited gold has found application in dentistry[7] because of its resistance to chemical attack and for use where a pure gold color is desired on nonprecious metals or alloys of gold. Such deposits, which are usually produced from cyanide solutions of low gold concentration, are very thin—approximately 0.000001 to 0.00001 inch. The maximum current density is limited to 0.86 amp. per square decimeter (8 amp. per square foot), and the rate of deposition is low. Thick deposits from these solutions tend to be dull, require periodic burnishing, and are relatively soft.

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†Degussa conductive silver 200.

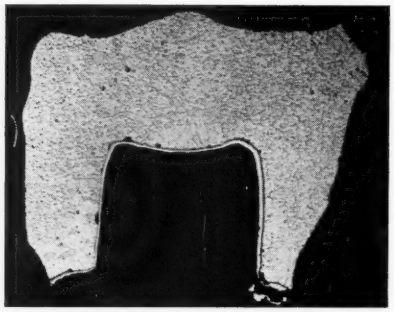


Fig. 1.—A section of a completed casting. The apparent gap between the gold matrix and cast alloy is due to differential etching. (×10; reduced ⅓.)

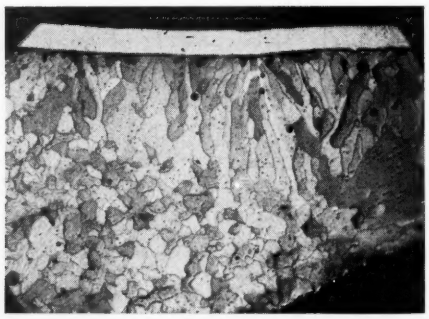


Fig. 2.—A section showing the interfacing of the gold matrix and the cast alloy. (×50; reduced ⅓.)

An important war development was the application of as much as 0.001 inch of gold on radar equipment.[10] In recent years, much attention has been focused on the production of thick, bright deposits of pure gold[11] and gold alloys[12-17] for use in the electronic and communication industries.

EQUIPMENT FOR FORMING THE GOLD MATRIX

The gold electroplating solution was contained in a 1 L. tank* immersed in a water bath which was electrically heated and thermostatically controlled. A mechanical stirrer provided rapid agitation. A rolled gold sheet was used as the anode. Direct current was supplied by a rectifier which was controlled by a variable transformer for experimental determinations, but a 2 V. lead storage battery and rheostat were used for producing the matrices (Figs. 5 and 6).

ELECTROPLATING SOLUTIONS

Several exploratory experiments were conducted with gold plating solutions. Gold chloride solutions containing 6.3 Gm. per liter (1 ounce per gallon) of

*Perspex.

gold and conventional cyanide solutions containing up to 3.15 Gm. per liter (0.5 ounce per gallon) of gold were used initially, but even at high temperatures, the current density was limited to 0.86 amp. per square decimeter. Current densities in excess of this produced granular and loosely adherent deposits. The production of smooth deposits from these solutions was slow, and the process required continuous attention.

The solution proposed by Kushner[18,19] gave smooth deposits 0.003 inch thick when a current density of 2.15 amp. per square decimeter (20 amp. per square foot) was used at a temperature of 57° C. Higher current densities produced coarse, burned deposits. The deposits contained 1 to 3 per cent nickel and tended to be too brittle for dental use.

In view of these results and because the presence of nickel introduced an additional variable, the nickel salt was eliminated. The free cyanide concentration was further increased to permit the use of higher current densities. Satisfactory matrices were obtained from the solution shown in Table I.

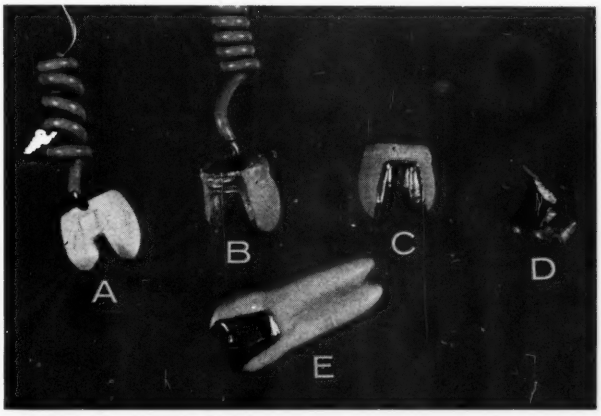


Fig. 3.—Steps in the inlay procedure: *(A)* a die with the conducting wire attached; *(B)* the metalized die; *(C)* the electroformed matrix on the die; *(D)* the wax pattern contoured and carved in the gold matrix; *(E)* the completed casting on the tooth.

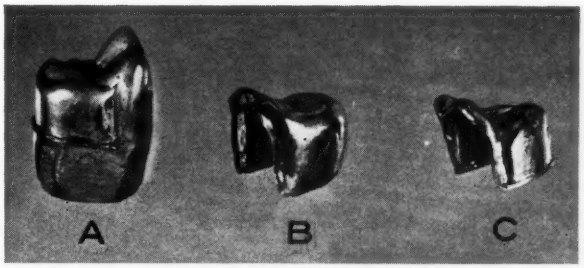


Fig. 4.—*(A)* The die of the prepared tooth; *(B)* the completed inlay cast on the matrix; *(C)* the gold matrix.

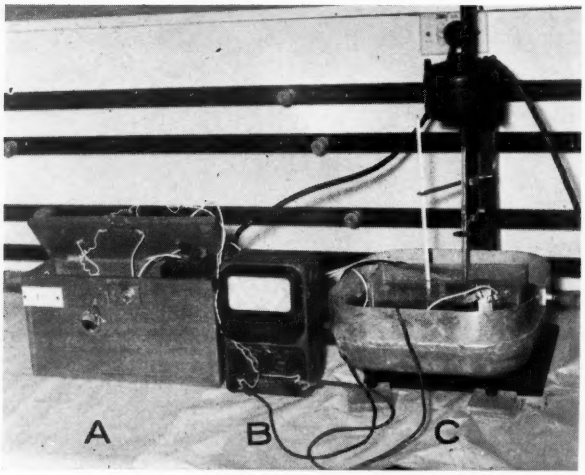


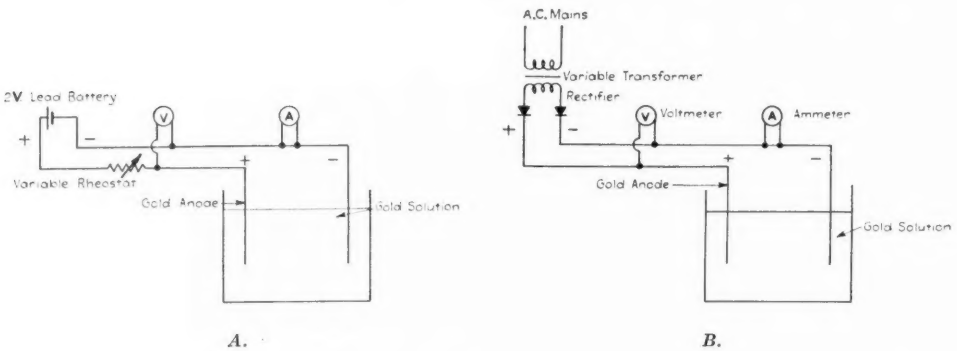
Fig. 5.—The equipment used for forming the gold matrix: *(A)* a unit containing a 2 V. storage battery and rheostat; *(B)* a multimeter; *(C)* the electroplating cell fitted with a stirrer immersed in a water bath.

PREPARATION OF THE SOLUTION

The solution was prepared as follows: 18.3 Gm. of potassium cyanide was dissolved in 500 ml. of distilled water at 60° C.; 14.1 Gm. of potassium gold cyanide was then dissolved in this, and 14.1 Gm. of potassium carbonate was added. Then, 11.4 Gm. of boric acid was dissolved in 150 ml. of distilled water at 60° C. and added to the solution. Distilled water was added to make a final volume of 1 L. The solution was allowed to stand overnight, then filtered prior to use. The entire operation was carried out under a hood because of the cyanide solutions.

OPERATING CONDITIONS AND EXPERIMENTAL RESULTS

The average current density employed was 3.2 amp. per square decimeter (30 amp. per square foot), and the temperature was maintained at 65° C. The voltage



A. *B.*

Fig. 6.—Diagrams of the electrical circuits. *A*, Circuit for forming the gold matrices. *B*, Circuit for experimental variations.

drop across the plating bath was 0.6 to 1 V. while the distance between the electrodes was 2 inches. The weight of the gold deposited per matrix was approximately 1 Gm., the average thickness of the deposit 0.005 to 0.006 inch. The throwing power of the solution was not measured, but the distribution of the metal was satisfactory (Fig. 7). When matrices were being produced, a current of 50 to 100 ma. was used for 1 to 2 hours, depending on the surface area and the shape of the metalized portion of the die. The deposited gold had a microhardness value of 64 (D.P.N. 25 Gm. load), while the value for annealed gold sheet was found to be 31 (Figs. 8 and 9). The electroformed gold presented no difficulties during subsequent manipulation and burnishing.

A series of experiments was conducted to determine the optimal conditions of operation. To facilitate the removal of the deposit, gold was plated on stainless steel cathodes having an area of 0.25 square inch. Temperature and current density were varied, and cathode efficiencies were determined. The hardness and microstructure of the deposits were examined (Fig. 10).

Smooth deposits of 0.004 inch thickness having a fine grain structure were obtained with a current density of 3.2 amp. per square decimeter in 1 hour at a temperature of 65° C. Current densities in excess of this led to the production of burned, powdery deposits (Fig. 11), while lower current densities produced deposits having a coarser grain structure. Interruption of the current supply caused the deposit to be laminated (Fig. 12). Smooth, fine grain deposits were produced at lower temperatures provided lower current densities were used, but this reduced the rate of deposition.

TABLE I. ELECTROPLATING SOLUTION

SOLUTION	GM.
Potassium gold cyanide	14.1
Potassium cyanide	18.3
Potassium carbonate	14.1
Boric acid	11.4
Distilled water	Quantity to make 1 L.

Fig. 7.—A cross section through a matrix. (×10; reduced 5/9.)

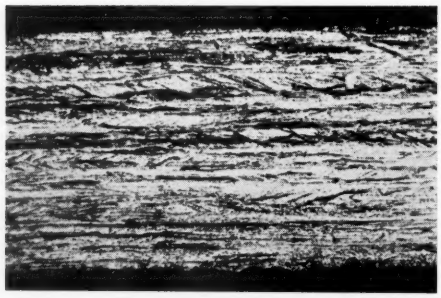


Fig. 8.—A section through a rolled gold anode. (×150; reduced ⅓.) (D.P.N. 87.)

Fig. 9.—A section through an annealed rolled gold anode. (×150; reduced ⅓.) (D.P.N. 31.)

At a temperature of 65° C., cathode efficiencies of 90 to 95 per cent were obtained. Anode efficiencies were above 100 per cent when the anode current density was below 0.86 amp. per square decimeter. When the anode current density exceeded this value, the anode efficiency was as low as 10 per cent although polarization films were not visible on the anode surface.[20] In order to prevent a reduction in the gold concentration of the solution which would occur from these conditions, the anode area was maintained at four times that of the cathode area so that the anode current density was below 0.86 amp. per square decimeter.

DISCUSSION

The pH of the solution during these experiments was constant at a value of 10.2 (electrometric), and the free cyanide concentration, which was determined at regular intervals, was maintained at 10 Gm. per liter by periodic additions of potassium cyanide. Distilled water was used to maintain a constant solution level. During one series of experiments, 14.2 Gm. of gold was deposited from 1 L. of solution and 16.5 Gm. of gold was dissolved from the anode. Thus, not allowing for dragout, the gold concentration of the solution had increased, and the deposit produced was still satisfactory. The use of a larger volume of solution would ensure a more constant concentration of metal, but this would be uneconomical. In the solution described, gold anodes could be replaced by insoluble anodes in the production of two or three matrices in every fifteen.

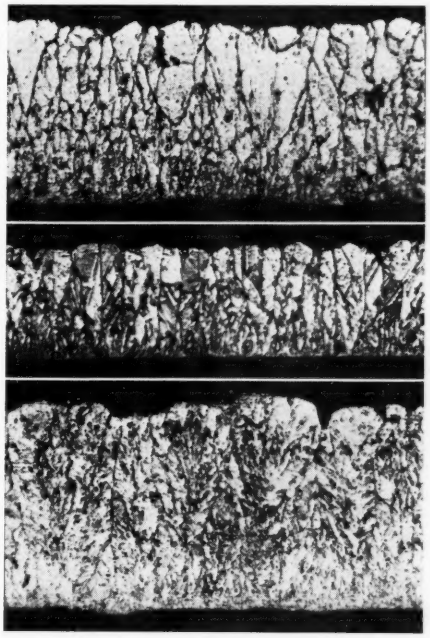


Fig. 10.—Sections through deposited gold showing the effect of current density. *A*, Current density 0.86 amp. per square decimenter (8 amp. per square foot); temperature 65° C.; mean D.P.N. 53. *B*, Current density 1.5 amp. per square decimeter (14.4 amp. per square foot); temperature 65° C.; mean D.P.N. 64. *C*, Current density 3.2 amp. per square decimeter (30 amp. per square foot); temperature 65° C.; mean D.P.N. 64. (×500; reduced ⅓.)

Fig. 11

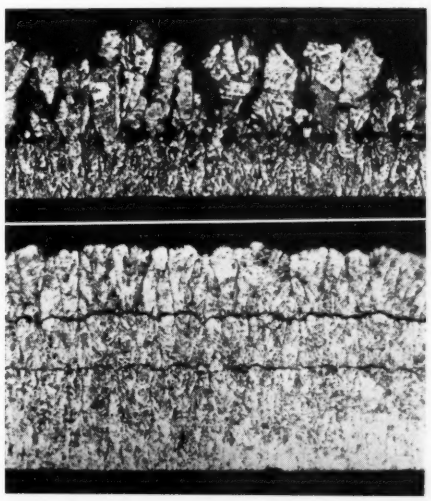


Fig. 12

Fig. 11.—A section showing the effect of excessive current density, 5.3 amp. per square decimeter (50 amp. per square foot); temperature 65° C. (×500; reduced ⅓.)

Fig. 12.—A section showing the effect of current interruption. (×500; reduced ⅓.)

For the successful operation of this solution, it is necessary to control the metal and the free cyanide concentrations. However, the life of the solution depends upon the accumulation of carbonates. When present in excess, carbonates which are formed by the oxidation of cyanide cause a loss of cathode efficiency, and the deposits obtained are unsatisfactory.

SUMMARY

A thick gold matrix has been produced by electroforming. Using the gold cyanide solution described, the matrix can be produced in 1 to 2 hours, the rate of deposition being 0.004 to 0.005 inch per hour at a temperature of 65° C. and a current density of 3.2 amp. per square decimeter.[2] This matrix can be adjusted in detail to the prepared cavity and the inlay completed by casting a suitable gold alloy into the matrix. The cast gold apparently forms an intermediate alloy with the pure gold matrix. The behavior of the electroplating bath and of the electrodes and the use of additive agents are being further investigated. Clinical applications are being investigated, and studies are in progress to produce an electroformed matrix that has a high melting point for use in ceramic restorations.

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MEANS OF SAVING MUTILATED TEETH

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MANY TEETH have been so mutilated by extreme caries or repeated fillings that they can no longer be restored by the usual means. To prevent loss, such teeth must be reconstructed or treated so that a nearly normal preparation may be obtained.

The purpose of this article is to describe several procedures that may be used for the satisfactory reconstruction of these mutilated teeth.

FRACTURED PERMANENT ANTERIOR TEETH IN YOUNG CHILDREN

Fractured permanent anterior teeth in young children have always presented problems, particularly in the group 7 to 15 years of age. The teeth have not fully erupted, and the placement of complete jackets or veneer crowns is contraindicated. The inability to extend the preparation far enough gingivally would mean that as the tooth continued to erupt, the cervical margin of the jacket or veneer crown would become progressively more visible. Then, for esthetic purposes, a second jacket or veneer crown would have to be made and possibly a third at a later date.

It is best to wait about 4 to 6 weeks after the injury to determine whether or not the fractured tooth will require endodontic treatment. If necessary, it should be completed. In either event, the location of the pulp chamber is determined with roentgenograms.

The fractured edge is smoothed or reduced to accommodate a gold wire loop (Fig. 1). The gold wire must extend below the prepared surface but 1 mm. short of the incisal edge of the normal tooth. A hole 3 mm. deep is drilled on both sides of the pulp chamber from the incisal edge with a cross-cut or plain fissure bur. These holes receive the U-shaped loop bent from 20 or 22 gauge round gold wire. The size of the wire used will depend on the labiolingual thickness of the fractured tooth. Because of the large pulp chambers found in young teeth, the holes should be located well toward the mesial and distal surfaces of the teeth, in dentin inside the dentoenamel junction. The ends of the gold wire loop should be serrated slightly with a metal or carborundum disk and then cemented into the tooth.

A resin crown form is cut and fitted to the tooth so that the labial surface is open but the incisal edge is retained. One of the self-curing acrylic resin filling materials is painted into the preparation by the brush technique. The material is allowed to cure, and the crown form is removed. The resin filling is shaped with sandpaper disks and polished.

*Assistant Professor.

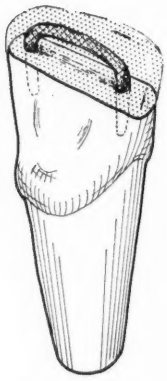


Fig. 1.—The wire loop is in place supporting the restored incisal edge.

This restoration requires a minimum amount of work on the patient and the fractured tooth. The restoration will last until a permanent jacket or veneer crown can be made. The resin may discolor in time, but the discoloration can be corrected easily by grinding off the old resin and replacing it with new. No extensive re-preparation is needed at the cervical part of the tooth to correct appearance because of continued eruption.

WIRE LOOPS FOR RETENTION OF SILVER AMALGAM UNDER FULL AND VENEER CROWNS

Many badly broken-down vital posterior teeth lack sufficient tooth structure for adequate retention for full or veneer crowns. The pulp has receded, and secondary dentin is present.

The location of the receded pulp is determined with roentgenograms. All unsupported enamel and carious dentin are removed. The pulpal floor does not need to be level. Four holes are drilled in the dentin of the occlusal surface, two toward the mesial surface and two toward the distal surface near the buccal and lingual dentoenamel junction.

The holes are 2 to 3 mm. deep and are drilled with a cross-cut or plain fissure bur to receive wire loops constructed of 20 or 22 gauge round gold wire. The

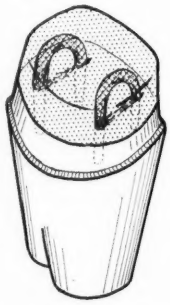


Fig. 2.—The wire loops are in place, and the occlusal surface has been built up with silver amalgam.

U-shaped wire loops should fit the holes and extend beyond the pulpal floor 2 to 3 mm. (Fig. 2). The ends of the loops are serrated with a metal disk and cemented into the tooth.

The remaining coronal portion of the tooth is tightly fitted with a copper band. The band is contoured at the cervical margin and cut to the desired occlusal height, allowing sufficient space for the gold occlusal surface on the finished crown. The cervical portion of the copper band is reduced in thickness with a sandpaper disk to reduce gingival irritation. This is important because it is necessary to leave the copper band in place for 24 hours after filling it with silver amalgam.

The silver amalgam is condensed well into the band, around and under the wire loops, and built up to the full height of the band. The external occlusal edge of the copper band is made smooth to avoid irritation to the tongue.

After 24 hours, the copper band is removed, and the crown preparation is finished in the usual manner.

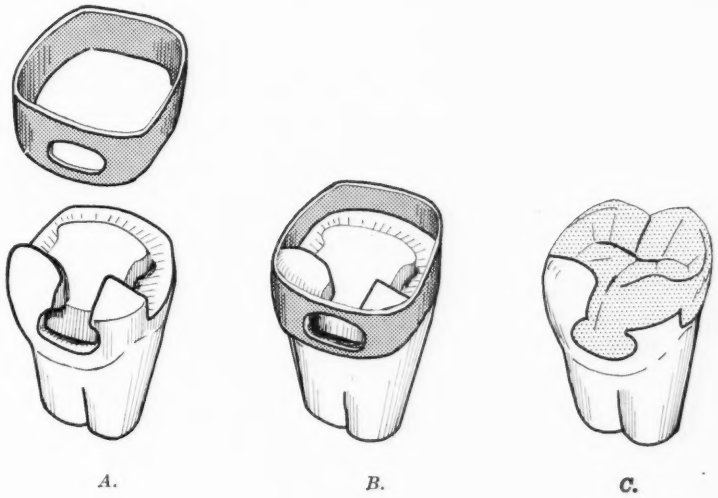


Fig. 3.—*A*, A preparation is made with a reverse bevel on the cervical floor and buccal extension. The cusp is reduced and the band is contoured. *B*, The copper band is fitted to the tooth with the hole over the buccal part of the preparation. *C*, The finished restoration.

Teeth restored in this manner provide a greater amount of stability and frictional retention for the crowns than would otherwise have been obtained. They can be used as single restorations or bridge abutments.

LARGE SILVER AMALGAM RESTORATIONS

It is often necessary to restore badly broken-down molar teeth with silver amalgam instead of a cast gold crown. In young patients, ready-made stainless steel crowns may be used. If only the buccal cusps or the lingual cusps remain, with a small amount of supporting dentin, the tooth can be restored satisfactorily with silver amalgam.

All carious dentin is removed, and the pulpal floor is flattened. As much of a box preparation is prepared on the proximal surfaces as remaining tooth structure permits. A shoulder is made from the cervical floor of the proximal box preparations completely around the lingual or the buccal surface, as the case may be (Fig. 3, *A*). A reverse bevel is made on the cervical floor of the box preparations and on the shoulder around the lingual or buccal surface, and a flat bevel is made on the cavosurface margin to prevent fracture of enamel rods. If added retention is needed, wire loops may be added (Fig. 2).

The remaining wall is cut through from the buccal or lingual surface with a small diamond wheel. The cut is widened with a No. 560 cross-cut fissure bur and extended pulpally 1.5 mm. below the dentoenamel junction. This is connected with a large buccal surface preparation which will serve as retention for the entire restoration (Fig. 3, *A*).

The remaining cusp or cusps are reduced in a horizontal plane a minimum of 1.5 to 2 mm. if they are not adequately supported with dentin. No cavosurface bevel is made on this cut.

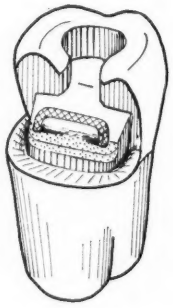


Fig. 4.—A wire loop is in position to retain a restoration.

A copper band is fitted tightly to the prepared tooth and contoured at the cervical margin (Fig. 3, *B*). The band is cut occlusally so that the opposing teeth do not contact it when the teeth are in centric occlusion or in lateral excursions. A hole is cut in the buccal surface of the band to provide access for the insertion and condensation of the silver amalgam. The cervical portion of the band is thinned with a sandpaper disk to reduce gingival irritation. The proximal surfaces of the band are thinned in the contact areas if there is to be contact with adjacent teeth. Wedges are placed in the interproximal spaces just below the cervical floor of the preparation.

Silver amalgam is thoroughly condensed into the band from the occlusal and the buccal surfaces. The external occlusal edge of the copper band is smoothed to reduce tongue irritation. The occlusal anatomy is carved starting with the central fossa, which should be well defined, and continuing to the mesial and distal fossae. The buccal and lingual grooves are tapered from the central fossa to the edge of the copper band. The patient is directed to close the teeth into centric occlusion and to

make lateral gliding movements, and a check is made for possible occlusal interferences.

The copper band is cut where there is remaining tooth structure and removed in 24 hours. Any overhanging margins are removed with files, fine tapered stones, or burs. The tooth contour and occlusal anatomy are refined with sandpaper disks, burs, and stones, finishing with fine sandpaper and Burlew disks, pointed brushes, and a prophylactic rubber cup with pumice. A final polish may be obtained with tin oxide and soft brushes (Fig. 3, *C*).

GOLD WIRE LOOPS UNDER LARGE SILVER AMALGAM RESTORATIONS

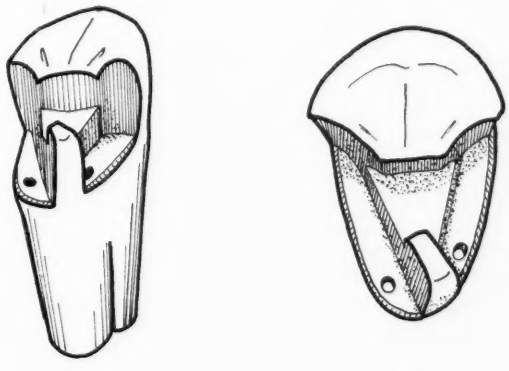
A preparation is made in the remaining, normal portion of the tooth in the usual manner. All carious dentin is removed. The location of the pulp chamber is determined with roentgenograms, and two holes are drilled 2 to 3 mm. deep into the dentin on the deep pulpal floor away from the pulp. A U-shaped wire loop is constructed of 20 or 22 gauge gold wire. The ends of the loop are long enough so that the loop extends slightly above the normal, prepared pulpal floor. The ends of the loop are serrated and cemented into the tooth with a sufficient amount of cement that the axial wall can be restored to the height of the prepared pulpal floor (Fig. 4).

The buccal and lingual walls of the preparation diverge slightly toward the cervical margin. A reverse bevel is made on the cervical floor with a flat cavosurface bevel.

A conventional matrix may be used for the insertion of the silver amalgam.

USE OF PINS TO AID IN RETENTION OF GOLD INLAYS

Not enough emphasis has been placed upon the careful use of pins to aid in the retention of badly broken-down teeth. The extensive loss of tooth structure does not always necessitate full coverage. The use of properly placed pins will provide many restorations with more than adequate retention.



A. *B.*

Fig. 5.—The position of the holes on the mesial and distal cervical floors of the preparation. *A*, Lingual view. *B*, Occlusal view.

In most cases, the bicuspids are the teeth involved. Because of their small size, especially if they have been previously restored with silver amalgam, the lingual cusp often fractures away from the restoration.

All remaining filling material is removed. The mesial and distal buccal walls are paralleled, and the pulpal and cervical floors are flattened. The cervical floor is extended lingually, retaining as much of the remaining lingual wall as possible.

A hole is drilled 2 to 3 mm. deep in the dentin on the mesial and distal cervical floors toward the lingual side of the cavity with a No. 701 tapered fissure bur (Fig. 5). The entire cavosurface angle on the buccal cusp and at the cervical margin is beveled. If the direct inlay technique is used, plastic pins are cut to fit the drilled holes and left extended above the cervical floor before insertion of inlay wax. If the indirect method is used, the impression material used is inserted carefully into the holes to avoid trapping air.

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OPERATIVE PROCEDURES ON MUTILATED ENDODONTICALLY TREATED TEETH

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ENDODONTIC THERAPY is preserving many teeth which otherwise would be considered hopelessly deteriorated, but with its utilization, the number of operative problems has increased proportionately.

Specialists in endodontics are qualified to treat seriously debilitated teeth that general practitioners may hesitate to attempt to restore. The treatment of multirooted teeth is becoming less of a challenge. The aseptic technique and the precision filling of root canals are far more common today than they were 10 to 15 years ago.[1] The public is far more dentistry conscious and is making greater demands on the profession to save rather than extract teeth. Economic conditions are such that a greater segment of the population can afford restorative dentistry.

Yet, in spite of the greater public awareness, many patients fail to seek treatment until they are in pain or have fractured a tooth or teeth. Years ago, the dentist would have reprimanded such a patient with "You've waited too long" or "You've come too late" and reach for the forceps. In recent years, the profession has been able to save such mutilated teeth and establish for these patients a new confidence in dentistry.

Root canal therapy utilized singly on a mutilated tooth does not save the tooth; instead, it saves the root. After endodontic therapy, whether performed by a general practitioner or a specialist, the dentist is still faced with the problem of restoring the crown and reinstating the tooth as a permanent, functional, and esthetic member of the masticatory apparatus.

WEAKNESSES OF ENDODONTICALLY TREATED TEETH

In the past, the profession has not been very successful with this facet of restorative dentistry. Far too often, the dentist is confronted with serious cervical subgingival fractures of crowns with apparently sound restorations and successful root fillings. He may fail to recognize the basic differences between a vital tooth and a pulpless one and that what may be sound for one may not be for another.

Badly broken-down pulpless teeth have a number of common characteristics: (1) They are brittle. Being deprived of a central blood supply, the dentin becomes desiccated and inelastic. (2) They possess little or no coronal tooth structure. The access opening for root canal treatment often extends onto the only intact surface

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of the tooth, leaving the crown completely undermined (Figs. 2 and 3). (3) They possess lowered resistance against decay and no longer have the faculty of detection of a developing lesion through pain. With the loss of the pulp, they have also lost the ability to form secondary dentin. Badly deteriorated pulpless teeth are, therefore, far more vulnerable than vital teeth.

Preparations can be designed to compensate for these weaknesses. An intelligent approach to the restoration of such teeth can prevent embarrassing mishaps and also enable the dentist to utilize strategic endodontically treated teeth as abutments for fixed and removable partial dentures (Fig. 1).

CAVITY DESIGN

Recent advances in cavity design for inlays that make use of modified slices to gain extracoronal support and the capping of cusps to resist fractures are proposed in the literature. These practices are becoming far more common in dealing with pulpless teeth in which a moderate amount of coronal tooth structure remains.[2]

The current methods for coping with those teeth which have lost the crowns but possess roots which are well supported by alveolar bone will be discussed.

Nature provided the chewing apparatus with anchorage in alveolar bone by means of roots and a periodontal membrane. When this remarkable form of anchorage is lost through the sacrificing of roots, the gingival mucosa provides a poor substitute for the support of a dentition. Modern endodontic therapy enables the dentist to save these roots. Restorative procedures following endodontic treatment enable one to utilize them with a prognosis that is favorable. These two procedures are not synonymous, although someday they may be.

OBJECTIVES OF OPERATIVE PROCEDURES

The ultimate aims of the operative procedures are (1) to completely restore natural form and function, (2) to give the tooth strength to resist the forces of mastication or any other forces that it may be subjected to during accidental trauma, possible clenching, or night grinding, (3) to protect it from the ravages of decay, (4) to restore the esthetic appearance whenever possible, and (5) to prepare the tooth as a possible abutment for a fixed or removable prosthesis.

To become useful members of the chewing apparatus, such teeth must be reinforced or supported with either an intracoronal "crutch" or an extracoronal "brace," or both, and they must be protected from the ravages of decay by adequate extension for prevention.

CRUTCH AND BRACE

The intracoronal crutch is a cast post or dowel which extends into a preparation made in the root canal and is continuous with a core. The post and core provide support and retention for the restoration to follow and are designed to prevent root fracture.

The extracoronal brace is a subgingival collar or apron of gold which extends as far as possible beyond the gingival seat of the core and completely surrounds the

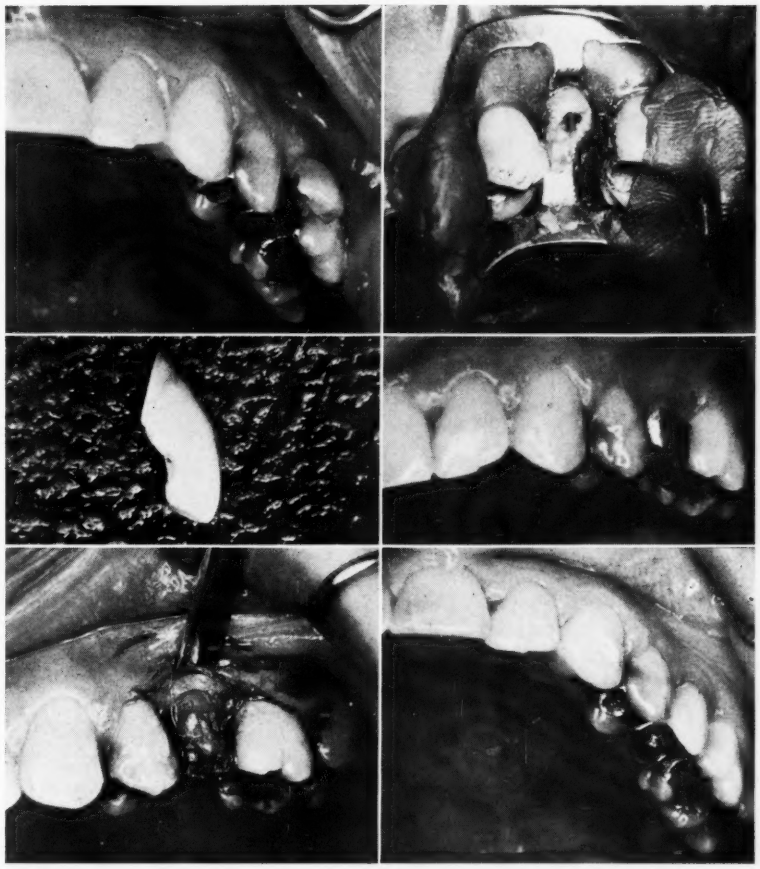


Fig. 1.—*A*, Fractures of the buccal cusp of unprotected pulpless upper bicuspids are seen frequently. *B*, The fracture extends below the epithelial attachment. *C*, Osteoplasty is performed to expose the root below the fracture line. *D*, A clamp is used to expose the stump. *E*, The post-core crutch is cemented. Note the healed gingiva 3 weeks after operation. *F*, A veneer crown with a subgingival apron of gold surrounding the perimeter of the root forms the brace.

perimeter of the cervical part of the tooth. It is an extension of the restored crown which, by its hugging action, prevents vertical shattering of the root.

By virtue of its exaggerated gingival extension, this apron of gold contributes to mechanical retention for the restoration as well as prevention of recurrence of decay in mouths which have little or no immunity against caries.

Posts for Single-Rooted Teeth.—The preparation for the post in a single-rooted tooth should extend as far into the root as the gingivoincisal or gingivoocclusal height of the crown (Fig. 4). It should taper slightly to enable withdrawal of a pattern without fracture or distortion and roughly conform to the shape of the root canal.

If the root canal tends to be round, the preparation should be distorted slightly to appear ovoid or square in cross section. This will prevent rotation of the post. There should be a definite gingival seat. The gingival seat is prepared in two planes

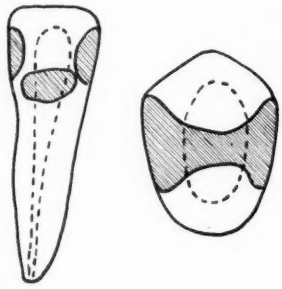


Fig. 2 Fig. 3

Fig. 2.—A typical incisor with mesial, distal, and cervical restorations. The access opening on the lingual surface, usually the only intact surface of the tooth, leaves the crown unsupported.

Fig. 3.—A typical upper bicuspid with an MOD amalgam restoration. The access opening extends onto the inclines of the buccal and lingual cusps, thus reducing their support.

when the reduction of the crown extends close to the gingiva, in order to prevent laceration of the interdental papillae. A shallow keyway or lock can be incorporated within the gingival seat to further prevent rotation. With this lock as a guide for insertion of the casting and the gingival seat as a definite stop, the possibility of root fracture through spreading of the walls during cementation of the slightly tapering post is eliminated.[3]

Posts for MultiRooted Teeth.—Posts for multirooted teeth need not be as long as for single-rooted teeth. Posts and cores for teeth with divergent roots are constructed in two or three sections. These are cemented in place independently and can be united with mortise joints or semiprecision locks to provide additional strength (Fig. 5).

RUBBER DAM APPLICATION

Proper isolation of the tooth to be prepared is probably more important in treating pulpless teeth than with vital ones, because it is difficult to achieve clear vision within a root preparation even under the most ideal conditions. The slightest miscalculation or momentary loss of control can lead to serious complications and may undo many hours of painstaking treatment.

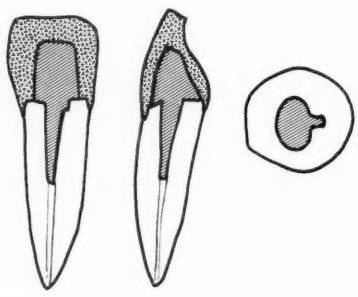


Fig. 4.—An intracoronal crutch and extracoronal brace for a pulpless incisor.

Since the dentin of the tooth root is a fairly soft tissue, good vision is more important than touch. In a dry, clean field, one does not readily lose sight of the pink gutta-percha point or the glistening silver pin. This prevents an accidental perforation of the root.

There is also some danger of withdrawing a poorly wedged silver point from the canal during the preparation of the tooth. If the silver point is accidently removed, the endodontic treatment must be repeated without contaminating the canal.

A good rubber dam application also facilitates making the wax pattern by eliminating moisture, and it prevents accidental burns of the lips or tongue with hot wax. It is often easier to make an accurate impression of a difficult preparation in a multirooted tooth by using the indirect method with a rubber dam. A well-prepared field encourages only the most meticulous operative technique.

A double-bowed clamp* is suitable for most anterior and bicuspid teeth (Fig. 6). If this clamp cannot retract the gingival tissue sufficiently from a seriously fractured tooth, a full quadrant rubber dam application must be made, and the tooth to be prepared must be isolated with a clamp† which can be blocked or secured with modeling compound to prevent displacement. Being narrower, these clamps produce better deflection of the gingivae to more effectively expose the root (Fig. 1, *D*). A variety of molar clamps are available, but none of them will serve in all conditions. If sufficient tooth stump cannot be exposed with a clamp

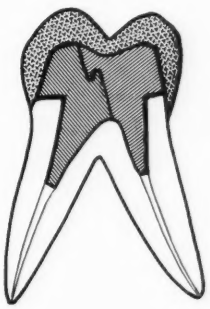


Fig. 5.—The double post and core for a lower molar with divergent mesial and distal roots are united with a semiprecision lock.

and the tooth is strategically important, gingivectomy or osteoplasty may be necessary. These procedures provide a longer clinical crown.[5]

The dentist must train himself to mentally "peel the soft tissue away from the tooth" in order to assess the true conditions. The clinical crown begins at the level of the epithelial attachment and not at the level of the crest of the gingiva. Rarely do lesions in teeth extend to the epithelial attachment except where a serious fracture has occurred. Then, bone trimming will enable proper isolation of the root

*Ivory No. 9.
†S. S. White No. 212 or Ivory No. 00.

stump to be made.[6] What at first seems to be a hopeless problem can be transformed into a gratifying challenge with ingenuity in isolating the field of operation (Fig. 1).

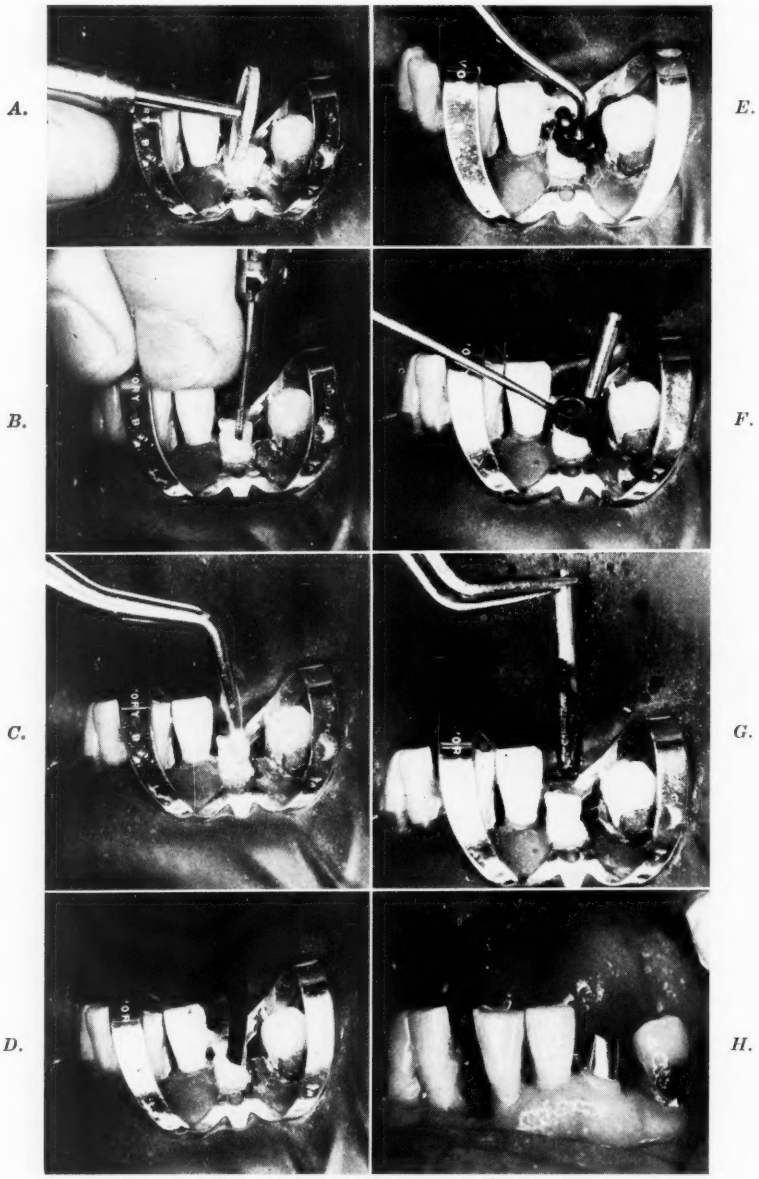


Fig. 6.—*A*, Gross reduction of unsupported coronal enamel to produce a gingival seat. *B*, The walls of the preparation are smoothed with a tapered fissure bur after the root filling has been honed out with round burs. *C*, The surface of the preparation is lubricated with Microfilm. *D*, Inlay wax is molded into the form of a plunger and forced into the preparation within the root canal. *E*, Wax is driven into the prepared canal with an amalgam plugger. *F*, Small increments of wax are added systematically to the core with a wax carrier loop. *G*, The pattern prior to investing. *H*, The cast post and core are cemented in the tooth prior to periodontal therapy.

INSTRUMENTATION

The gingival seat is prepared by quickly reducing unsupported enamel with a ½ or ⅝ inch diamond wheel stone or a heatless stone (Fig. 6, *A*). If so little dentin remains in the clinical crown that the preparation approaches the level of the gingiva, this reduction is accomplished in two planes, the labial and lingual. This will produce a gingival seat similar to that used for Davis or Richmond crowns. The reduction in two planes prevents laceration of the interdental papilla.[4] This preparation differs from the original Davis and Richmond crown preparations in that the entire clinical crown is not arbitrarily reduced to the level of the gingival tissue but only until a substantial thickness of dentin is approached.

By use of a sharp round bur the diameter of which is slightly larger than that of the pulp canal, the root filling is carefully reamed out. The *slowest* rotational speed and a jet of air are used to keep the field of operation unobstructed. The diameter of the bur is reduced as the root canal tapers. The root filling is removed by intermittently cutting 1 to 2 mm., then withdrawing the bur to eliminate undesirable undercuts from the walls of the canal. The pink gutta-percha point or the glistening silver pin must be kept in sight.

Fig. 7.—A rubber-base impression of an upper first bicuspid with divergent buccal and lingual roots.

When a depth equal in length to the clinical crown is approached, a tapered fissure bur is used to smooth the cavity walls, provide the necessary taper, and accentuate the form of the preparation to provide maximum retention and minimum rotation (Fig. 6, *B*). This often involves cutting a little to the side of the outline of the root canal in certain areas, particularly when the canal is perfectly round. A post hole which is ovoid or nearly square in cross section is desirable. This feature, in conjunction with a small shallow dovetail or recess cut into the gingival seat with the same tapered bur, will provide a stable positive seat for the final casting (Fig. 4).

Whenever access permits its use, a straight handpiece and direct vision should be employed in preference to the contra-angle handpiece with mirror vision because the former is easier to control (Fig. 6, *B*). If the contra-angle is used, the miniature head with a regular length bur will provide a longer shank for cutting to the

desired depth in the canal. Burs with extra long shanks and engine reamers are also available for this purpose.

For multirooted teeth, the approach is similar to that for single-rooted teeth, except that the diverging posts need not be as long in relation to the length of the crown. These posts are cast in two or three units, and the cores may be united with semiprecision attachments (Fig. 5).

An alternate method for removing gutta-percha from the pulp chamber and lumen of an endodontically treated tooth without enlarging the diameter of the canal makes use of the heated end of a straight explorer.* In narrower canals, once the constriction is approached with the hot explorer, the dentist must resort to a round bur to establish sufficient length for the post. As with the other technique, the final outline and taper are formed with a tapered fissure bur.

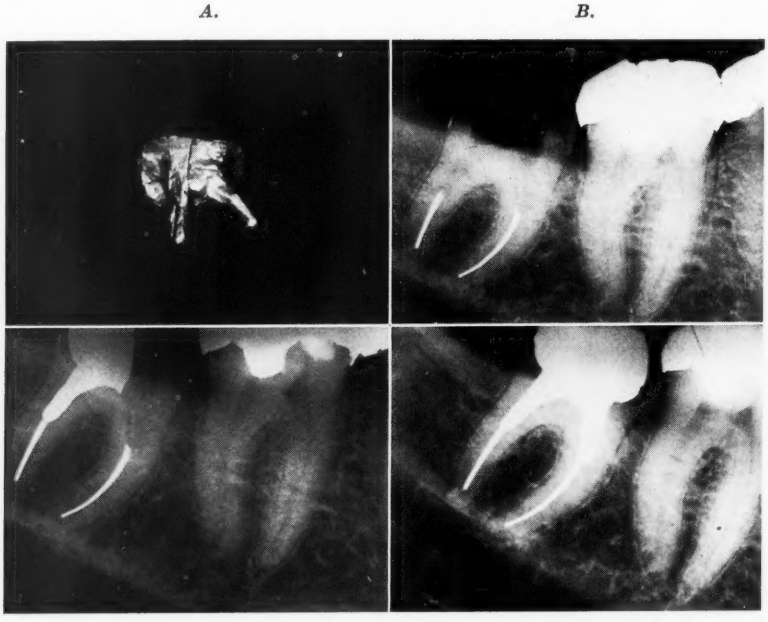


Fig. 8.—*A*, A double post and core for a fractured, previously treated lower third molar are constructed from a rubber-base impression. *B*, The preparations in the divergent root canals. *C*, The post and core are cemented into the distal preparation. *D*, The post and core are cemented into the mesial preparation with a semiprecision lock.

With canals that have been sealed with a silver point, some of the root canal sealer is removed from between the point and the walls of the canal by using either the heated end of an explorer or a half round bur rotating at very slow speeds. Once the desired depth is approached, the silver pin is nipped off with an inverted-cone bur rotating in reverse.* The final form of the canal preparation is established with a tapered fissure bur

*D. C. Gordon: Personal communication.

MAKING THE WAX PATTERN

The direct method of making a wax pattern is indicated for single-rooted teeth where good access is obtainable (Fig. 6, *C* to *H*). This method is accurate, simple, and not time consuming. It enables the core to be contoured precisely where good alignment is required for abutment teeth or when harmony with adjacent teeth is important.

The indirect method of obtaining a wax pattern is used for all multirooted teeth when paralleling of the posts is not possible because of excessive divergence of the roots.

Direct Method.—The surface of the preparation is well lubricated with Microfilm (Fig. 6, *C*). A stick of blue inlay wax or green wax* is gently heated over a Bunsen flame, and the softened end is molded into the form of a long, thin plunger

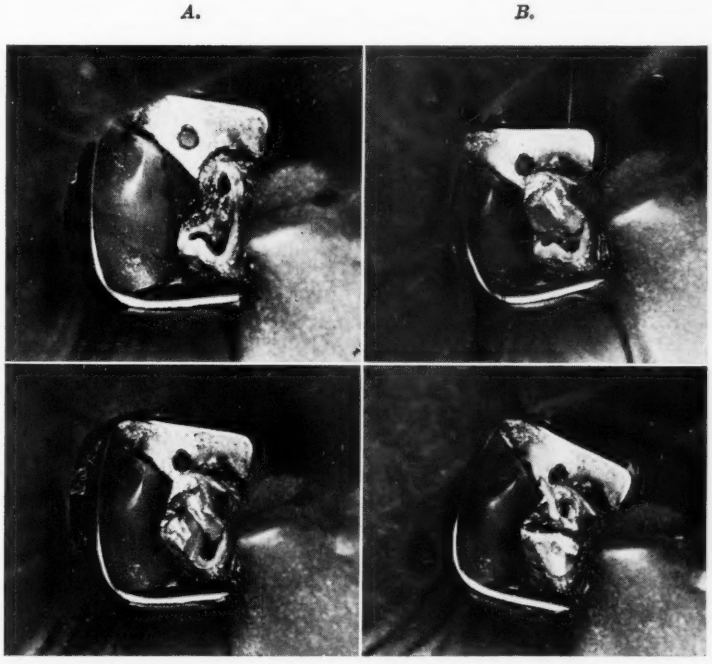


Fig. 9.—*A*, A preparation for triple post and core components for an endodontically treated upper second molar with divergent roots. *B*, The post and core are cemented into the lingual preparation. *C*, The post and core are cemented into the distobuccal preparation. *D*, The post and core are cemented into the mesiobuccal preparation. Mortise joints unite the three cores. To facilitate their try-in and removal, the sprue is cut off only after cementation.

(Fig. 6, *D*). It is cut from the body of the stick of wax with a heated Ward carver and forced into the post hole. Using an amalgam plugger, the wax is driven as far into the prepared canal as possible (Fig. 6, *E*). At this point, a discarded tapered fissure bur is heated in a Bunsen flame. The warm metal is driven into the wax with a pumping action, and the wax is coaxed into the preparation.[7] Heating of

*Mave No. 3.

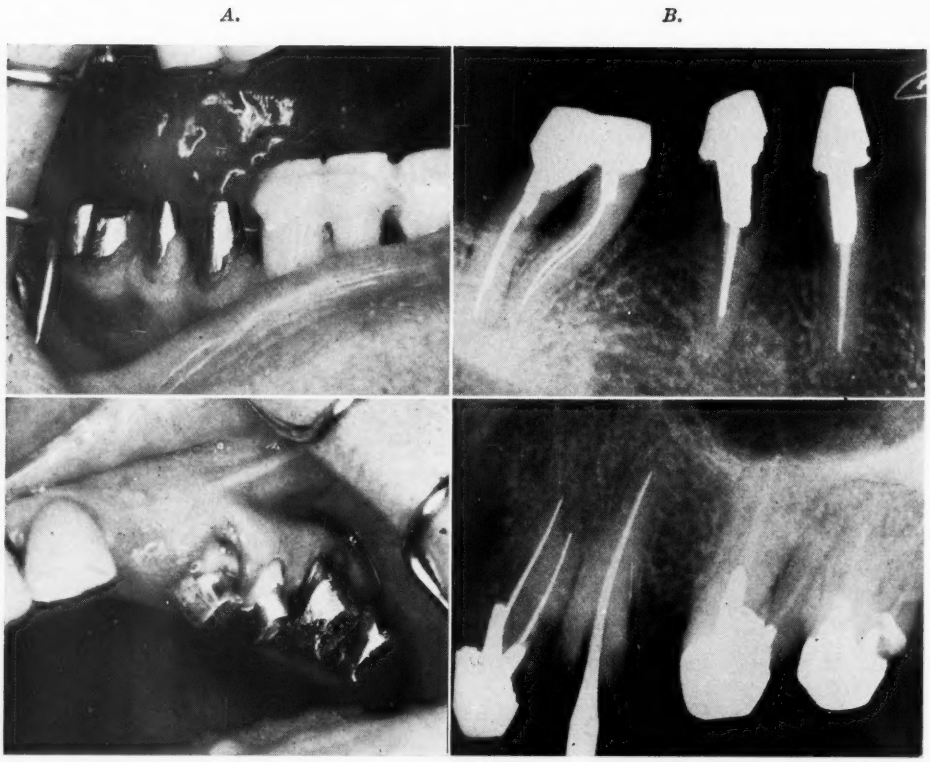


Fig. 10.—*A*, Strategic, pulpless lower right first bicuspid, second bicuspid, and first molar teeth have cast gold foundations to be utilized as abutments for a major splint. Root canals need not be refilled if the lamina dura is intact. *B*, A roentgenogram of the lower right quadrant. *C*, Strategic, pulpless upper left first bicuspid, second bicuspid, first molar, and second molar teeth have been salvaged with cast gold foundations and are to be used as abutments for a major fixed restoration. *D*, A roentgenogram of the upper left quadrant during the preparation of the second bicuspid.

the bur ½ inch from the end rather than at the end permits the wax to be more readily drawn to the bottom of the prepared post hole. The bur is removed, and the amalgam plugger is used again to force the resoftened wax to the base of the preparation and into the recess for preventing rotation. This softening, pumping, and plunging may be repeated several times. Finally, when the canal seems filled with wax, the heated bur is forced into it as far as it will go and left there to cool (Fig. 6, *F*). Excess wax ejected from the top of the canal is molded with a carver to the shape of the core. The pattern is withdrawn and inspected for detail and possible undercuts. It is inserted and withdrawn several times until it can be removed freely from the post hole without drawing out any wax. It is tested for stability and retention.

Once satisfied with the fit of the pattern and the path of withdrawal, the preparation is relubricated with Microfilm and the wax post reseated. Discrepancies in the core are filled in with wax using a wax carrier loop.[7] This instrument can be

made by bending a loop into the end of an old explorer or by placing a loop made of 23 gauge wire into a broach holder (Fig. 6, *F*). In this way, small increments of molten wax can be accurately deposited wherever they are needed, the size varying with the diameter of the loop. The margins at the gingival seat are resealed. Where possible, the occlusion is checked to allow clearance for the restoration to follow. The core is carefully contoured and smoothed using the adjacent teeth as a guide. The pattern is removed, invested, and cast. The used tapered fissure bur performs a triple function as a plunger, a support for the wax, and a sprue. Ultimately, a casting is obtained which cannot rotate within the preparation and which provides maximum support and retention for the restoration to follow (Fig. 6, *G* and *H*).

Indirect Method.—The fabrication of several interlocking castings by the direct method for an area of the mouth in which access is unfavorable would involve a number of tedious appointments in the hands of even the most skilled dentist. Fortunately, there is no longer a need for this approach.

Lengths of brass pins, steel wires, or nylon bristle ½ inch are cut to fit the prepared post holes loosely. If brass pins are used, one end of each of the pins is trimmed to form a square handle which also provides some mechanical retention for the impression material. If nylon bristles are used, one end is passed through a flame to produce a knob for the same purpose. The pins are coated with rubber adhesive. A suitable acrylic resin tray is prepared for the heavy-bodied rubber-base impression material, and its inner surface is coated with rubber adhesive.[8]

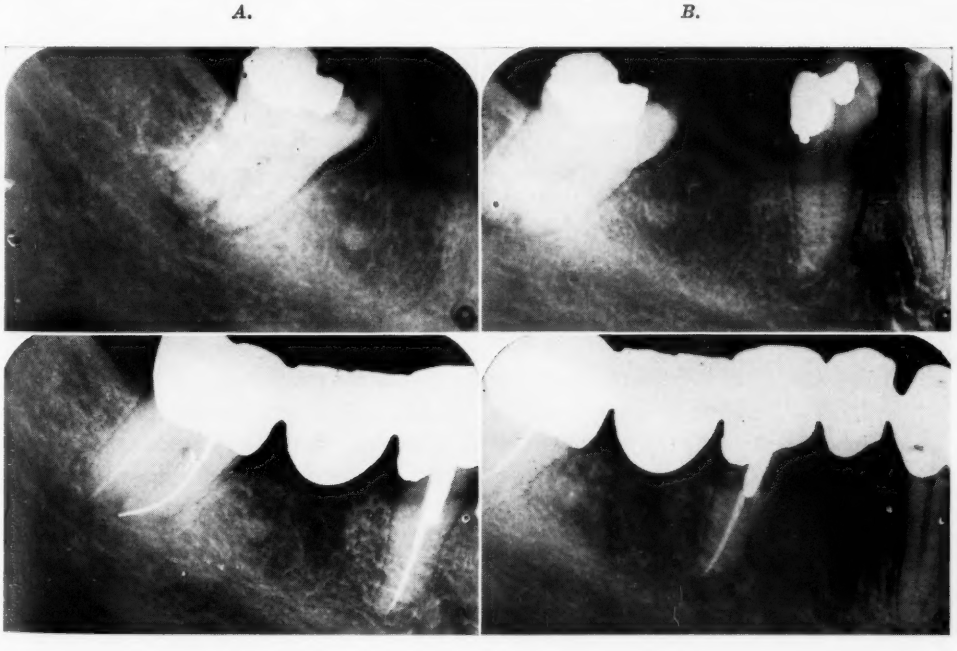


Fig. 11.—*A* and *B*, Strategic lower right second bicuspid and second molar teeth with necrotic pulps. *C* and *D*, The same teeth after 4½ years of service as abutments for an extensive splint. The bicuspid has a crutch and brace, the molar a brace only.

Often, an unannealed copper tube can be used as a matrix for the heavy-bodied impression material because an impression of the prepared tooth can be obtained without removing the rubber dam and clamp from the tooth. An acrylic resin plug confines the impression material in the band and facilitates removal of the band without distortion (Fig. 7). The only disadvantage of this technique is that an accurate impression is made of only the prepared tooth, without indicating its relation to the adjacent teeth. A plaster, wax, or alginate index can be made after the rubber dam is removed. This index will relate the prepared tooth to its adjacent teeth with sufficient accuracy for construction of a core.

The light-bodied impression material is pumped into the post holes with an explorer, and each of the coated pins is plunged into its respective preparation. The tray or copper tube loaded with the heavy-bodied material is seated over the tooth or teeth and allowed to polymerize thoroughly (8 minutes). The impression is removed from the tooth with a quick snap.

The pins provide support for the light-bodied material that adheres to them. Although no portion of the post can bend upon removal of the impression, the whole pin will move freely within the rubber material to allow withdrawal without distortion. An accurate impression of the diverging post or dowel preparations in each of the roots is thus achieved.

The impression may be silver plated, or a die may be poured in stone (Fig. 7).

LABORATORY PROCEDURES

Posts and cores for lower molar teeth can usually be made in two sections, a distal section which is waxed and cast to insert into a preparation made in the distal canal and a mesial section which usually inserts into preparations made in the two mesial canals (Fig. 8). The semiprecision lock cut into the distal core parallel to the preparations in the mesial canals serves to unite the two castings.

If the two mesial canals are too divergent, so that the preparations in these canals cannot be cut parallel to each other, separate castings must be made to insert into each of these canals, making the ultimate crutch for such a tooth a three component restoration.

Likewise, most upper molars can be treated with two castings, a lingual casting which inserts into the preparation made in the lingual canal and a buccal casting which inserts into preparations made in the two buccal canals. Occasionally, when the two buccal canals are too divergent, a three component interlocking restoration must be used (Fig. 9).

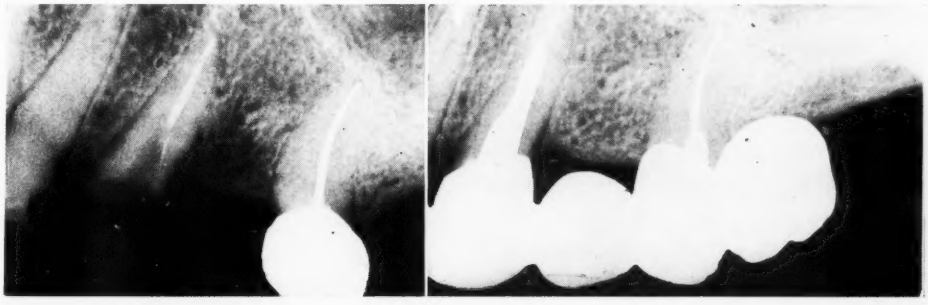
Most upper first bicuspids can be treated with a single casting. However, when the buccal and lingual roots diverge excessively, a two unit interlocking restoration must be made (Fig. 7).

CONSTRUCTION OF THE BRACE

The bracing action is usually achieved with a separate casting, the preparation for which is made after the components of the crutch have been cemented into the

root preparations. Bracing is achieved by extending the preparation as far as possible beyond the gingival seat of the crutch, usually to a fine chamfer (Figs. 4 and 5). This procedure can be accomplished with small cup-shaped disks at conventional rotary speeds or with finely tapered diamond points at ultrahigh speeds. The final casting, whether it be a full cast crown, a veneer crown, or a cast thimble, possesses a feather edge extension or apron of metal which exerts a clinging action on the perimeter of the root.

One of the complications of the exaggerated subgingival extension of these preparations is the difficulty of achieving adequate retraction of the gingival tissue when the impression is made. When a successful tray impression cannot be made, a copper band must be used. Regardless of the impression material used, an accurate impression of the cervical finish line will be obtained if a copper band is properly festooned.



A. *B.*

Fig. 12.—*A*, A strategic upper left cuspid root after a Davis crown was lost because of recurrent decay at the gingival seat and within the dowel preparation. *B*, The same tooth 2 years afterward as an important abutment in an occlusal rehabilitation after a new post and core were constructed.

When necessary, the post and crown can be constructed as a single casting and cemented as one unit. If the rubber-base impression technique is used, one is often tempted to use this simplified approach. However, the construction of a post and core to be cemented first, followed by the construction of a crown, has a number of decided advantages: (1) the retention and stability of the post can be tested critically and improved, if necessary, prior to the construction of the crown; (2) the crown preparation can be made more easily and more precisely with a core present to provide a frame of reference during the preparation of the shoulder, chamfer, or finish line; (3) if wear, fracture, excessive recession of the gingiva, or periodontal surgical operation necessitates remaking a crown, the procedure is a simple one with no element of risk; (4) if, in the future, the tooth in question is required as an abutment for a fixed or removable partial denture or a splint, it can be utilized without endangering the root; and (5) the alignment of teeth to be used as abutments is simplified.

CRITERIA FOR SELECTION OF TEETH TO BE TREATED

In determining whether a specific tooth is eligible for this type of treatment, the dentist must (1) establish that the root canal therapy has been successful, as demonstrated by the absence of an apical pathologic condition and by the presence of an intact lamina dura as observed in roentgenograms (Figs. 10 and 12), and (2) carefully assess the strategic importance of the tooth as it affects the total treatment plan.

FACTORS AFFECTING THE CHOICE OF TREATMENT

All teeth with a small diameter at the neck require the support of both a crutch and a brace when little or no coronal dentin remains. Most teeth which are broader at the neck, such as molars, can be treated by exaggerated subgingival extension alone, provided there is a reasonable amount of coronal dentin remaining (Figs. 11 and 12).

CONCLUSIONS

1. Operative procedures following endodontic therapy are as important as the root canal treatment itself. It is a responsibility of the dentist to provide this service.

2. Well-supported mutilated endodontically treated teeth can be restored functionally and esthetically and also utilized as strategic abutments for major restorations with a favorable prognosis.

3. The close integration of the specialties in dentistry has opened up new horizons for the general practitioner as well as the specialist.

4. Simple operative procedures have been reviewed. The procedures are no more difficult than making a gold foil or inlay restoration, and they enable the dentist to save and make maximum use of strategically important teeth.

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SURGICAL PROSTHESIS

PROSTHETIC SPLINTS AS AN AID IN THE TREATMENT OF HEMOPHILIA

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CONTROL OF POSTOPERATIVE oral bleeding in hemophilic patients is of particular concern to the oral surgeon. Many of these patients neglect their teeth because of a fear of bleeding and, as a result, frequently require surgical operation in many different parts of the oral cavity. The danger of bleeding dictates that surgical correction be confined to small procedures, which increases the number of operations required.

HISTORY

Various prosthetic aids have been constructed and described. Metal splints were described by Felix.[1] Rigid acrylic resin or modeling compound splints have been constructed, lined with a hemostatic agent, and placed in the mouth for periods ranging from 20 minutes to 5 days.[2-5] Results have varied from a successful application[1] to the report that the splint was an irritant to the wound.[2]

Splints in themselves are not a cure for hemophilia but are an adjunct to the complete therapy that is necessary for control of bleeding.

ELASTIC SPLINTS

Acrylic resin products vary considerably in their elasticity. This elasticity makes possible a different approach to the subject of splinting. Rigid acrylic resin splints create trauma and can be a detriment rather than an asset to clotting and healing.

Two relatively elastic resins have been used successfully for 6 patients. The bulk of the splint is constructed of a heat-curing acrylic resin and a cold-curing ethyl methacrylate resin is used for relining. Most of these splints have been used for 1 or 2 surgical procedures in the same dental arch. However, one splint was used for four operations. One tooth was extracted in the first operation, two teeth in each of the second and third operations, and five teeth in the fourth.

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*Professor and Chairman of the Department of Prosthodontics.

TECHNIQUE OF CONSTRUCTION

Maxillary and mandibular impressions are made in irreversible hydrocolloid, and the casts are poured in artificial stone. A wax interocclusal centric relation record is made, and the casts are mounted on an articulator without the use of a face-bow. The vertical dimension of occlusion is increased by 1 mm.

Undercuts are *not* blocked out, and the wax-up is completed over the maxillary cast. The wax is 1 mm. thick on the occlusal surfaces of the teeth, while in other parts it ranges up to 2 mm. in thickness. The maxillary palatal wax is extended from the gingival line 5 to 10 mm. toward the center of the palate in an arch shape. The distance lingually varies according to the size of the upper dental arch. Labial and lingual flanges are formed to the full extent of the mucobuccal fold and distally to the tuberosities filling the pterygomaxillary notches. Shallow impressions of the lower teeth are made in the occlusal surface of the wax splint.

The flasking and packing procedures are similar to those used for any heat-curing resin. However, the curing time *must* be controlled at 165° F. for 8 hours.

A heat-curing ethyl methacrylate resin* with controlled resilient properties is used in a 2.5 :1 ratio. Variations in the ratio alter the degree of resiliency. This ratio is an increase over the mixture normally recommended by the manufacturer for use as a mouth guard.

At the completion of the curing and cooling periods, deflasking is performed in the usual manner except in the removal of the cured splint from the cast. This procedure is simplified if the cast and splint are placed under hot water for several minutes, after which the splint can be carefully teased from the cast. Excess flash is removed, and rough and final finishing procedures are completed with acrylic resin trimmers, burs, pumice, and polishing agents.

The splint is inserted and worn by the patient for several days to test for trauma. The splint is prepared for final insertion by sterilization in 1 : 1,000 benzalkonium chloride aqueous solution.

Immediately following the completion of oral surgical procedures, a soft cold-curing ethyl methacrylate resin† is placed in the splint over the operative region, and the splint is inserted into the mouth. After 1 minute, the splint is removed, and the excess soft resin is removed. Partly denatured gelatin and thrombin are placed in the socket, and the splint is reseated in the mouth and allowed to remain for a period of 5 to 7 days. Since splints are used for multiple operations, the splint must be relined in each new operative site and firmly placed in position. Splints that are not seated properly become loose, as will those that are too flexible.

DISCUSSION

Although this splint is semirigid and holds its shape at mouth temperatures, it also has sufficient flexibility to allow it to enter average undercuts and interproximal spaces without pain or injury. Close adaptation to interproximal spaces aids in

*Impak.
†Oryl-Soft.

retention, especially after several surgical procedures have been performed. Strength, controlled rigidity, and broad tissue coverage are necessary to create constant pressure on the surgical area.

Denture abrasions may develop postoperatively at times when it is not advisable to remove the splint if a trial wearing period is not possible. Light abrasions may be relieved or treated by topical anesthetics, but prevention is by far the best treatment. The trial testing period is made possible by leaving the teeth that are to be extracted on the master cast. The void occurring in the splint because of the extractions is filled at the time of operation with the ethyl methacrylate resin. If the trial period is not used, it is sometimes difficult to determine whether postoperative complications are caused by the splint, postoperative trauma, or infection.

CONCLUSIONS

1. It is possible to construct resin splints that aid in the control of bleeding in patients with hemophilia.
2. A heat-curing ethyl methacrylate resin is satisfactory for the body of the splint because its properties permit control of the degree of rigidity.
3. A cold-curing ethyl methacrylate resin is satisfactory as a relining material placed over the operative site, since it maintains constant pressure and is nonirritating to the soft tissues.
4. The use of trial testing periods offers opportunities to relieve traumatic abrasion prior to the final insertion of the splint.
5. With careful insertion, seating, and relining, a single splint can be used for more than one surgical procedure in the same dental arch.

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READERS' ROUND TABLE

PHILADELPHIA, PA.

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY:

I have read THE JOURNAL OF PROSTHETIC DENTISTRY since its introduction, and I have been favorably impressed with the quality and beneficial value of most of its contents.

I was quite disturbed in reading the article by Dr. Stanley Behrman in the May-June, 1961, issue entitled "Surgical Preparation of Edentulous Ridges for Complete Dentures" (11:404-413). In this paper, Dr. Behrman makes the statement: "Problem mouths confront the prosthodontist when patients become edentulous after treatment by the schizoidontist, the paranoidontist, or the periodontist." I was unaware of Dr. Behrman's psychiatric training that has enabled him to classify dental practitioners into these groups on the basis of their therapeutic approach to the natural dentition. If he is using the term schizoidontist or paranoidontist as a name one can apply to those providing inadequate dental treatment, I think it is in extremely poor taste. Dr. Behrman lists himself as an assistant professor in a teaching institution. I wonder how effective a teaching method it is to criticize those who are not rendering an ideal dental service as either schizoid or paranoid. Knowing that your JOURNAL is placed in many libraries (medical and dental) throughout the world, I was rather surprised that the editorial board approved of the application of such nomenclature to dental practitioners.

I was appalled that Dr. Behrman feels that the periodontist is responsible for the problem mouths confronting the prosthodontist. He makes the statement: "Unfortunately, when the periodontist condemns a tooth, most, if not all, of the supporting alveolar bone has been lost. The patient, the recipient of the most judicious attention, now is left edentulous with little or no residual alveolar ridge." Later on in the article, he refers to edentulous mouths after treatment by the paranoidontist and the periodontist. I am very much interested in the evidence that supports the hypothesis that early removal of periodontally involved teeth preserves more of the alveolar process for complete dentures than the removal of teeth with more advanced periodontal conditions. I have heard this statement made before, but I have been unable to find any research to support this viewpoint.

In contrast, I have heard many clinicians say that the amount of resorption of the alveolar process following the removal of the teeth is the same regardless of the amount or type of periodontal involvement present. In this era of increased emphasis on dental research, the problem of alveolar resorption after the extraction of teeth should be thoroughly investigated. Until that is done, I do not believe that the periodontist, who is conscientiously trying to preserve the natural dentition and the alveolar process which exists for the natural dentition, should be criticized by Dr. Behrman or others as responsible for the problem mouths that confront prosthodontists. I believe that all periodontists would object to being classified in a category with the schizoidontist or paranoidontist. I hope these terms do not appear in print again.

Sincerely,

D. WALTER COHEN, D.D.S.

Note.—The editor interpreted the use of these coined words to be poetic license for the purpose of calling attention to a situation that does exist. He has great admiration for the work being done by *good* periodontists and *good* dentists and certainly wishes to do them no harm. Honest criticism and re-evaluation are essential to progress. The editor felt that Dr. Behrman was honest in pointing out things that he believes to be wrong, in some instances. The obvious exaggeration of the coined terms themselves should make it apparent that they did not apply to all dentists or to all periodontists. These coined words will not be used in future articles.

CARL O. BOUCHER, EDITOR

NEW YORK, N. Y.

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY:

Rereading the first four paragraphs of my article will distinctly show that Dr. Cohen's suspected indignity is delusionary. The free and jocose extensions of the dictionary definitions of schizoid and paranoid should be recognized as literary license.

Absolutely no criticism of periodontists was intended. I do not believe in guilt by association. Actually, some of my best friends are periodontists. Nowhere in my article is the periodontist held responsible for alveolar bone loss. The fact remains that when, in spite of his expert treatment, "the periodontist condemns a tooth, most, if not all of the supporting alveolar bone has been lost." This is as it should be. If instead Dr. Cohen would urge periodontists to condemn teeth while substantial alveolar bone remains, he is at variance with the rest of his *confrères.*

Nowhere in my article is there any suggestion that extractions will preserve bone. Instead, it is clearly stated that for the edentulous patient, ". . . the same dyanamism which caused the alveolar bone to disappear may still be at work. . . ."

The prosthodontist's problem is essentially the same whether the alveolar bone is missing as a result of overenthusiastic surgical procedures or periodontoclasia.

Sincerely yours,

STANLEY J. BEHRMAN, D.D.S.

LOUISVILLE, KY.

EDITOR, THE JOURNAL OF PROSTHETIC DENTISTRY, AND
DR. D. WALTER COHEN:

Thanks for your note of May 23 and the copy of your letter to the editor. A copy of this letter will go to him so he can see that I agree and disagree with you at the same time. I believe that Dr. Behrman's article is a good one, following a number of previous articles of his on surgical procedures, magnetic implants, etc., that indicate that he is a conscientious, serious-minded contributor to the field of prosthetic dentistry. I have seen some of his work and am happy to have a man of his caliber directing his thinking toward better denture service. I feel that Dr. Behrman's use of the terms paranoidontist and schizoidontist is unwarranted and somewhat facetious, and I am sorry that Dr. Boucher allowed those words to pass his editorial screen. I think it was ill-advised, particularly, as you say in your letter, since the JOURNAL goes into school libraries and into the hands of students all over the world and could be misinterpreted.

I recently took Henry Goldman's advanced course in periodontics at Boston University. That, following the fine course I took with you and Morton Amsterdam 2 years ago, has taught me a great many things a prosthodontist should know. I am treating the periodontal structures

and retaining teeth that 10 years ago would have been extracted, and in doing so, I feel that better service is being rendered to the patient. I make far fewer complete dentures now than formerly, and only time will tell if I have the skill to do the job properly to justify the extensive surgical procedures and financial burdens placed upon the patient. So far so good, but I am a novice at it, and I believe there are many other novices doing the same as I am doing.

There is another side of the coin. During the first 15 years of my practice I had a neighbor who was a periodontist. He is long since dead. He practiced before extensive surgical procedures were used, but he had a practical knowledge of occlusion. He spent hours at root planning and at root polishing on each patient. I saw and worked on many of these patients. Their teeth, roots included, were as highly polished as newly glazed porcelain, and the gingival tissue usually looked healthy. Home care, massage, and stimulation were stressed and most of his patients were comfortable and happy. This man held on to teeth until they were as loose as piano keys. Every now and then a patient would lift a tooth out, and after a few more were gone, the periodontist would prescribe a removable partial denture. This gave me an opportunity to observe the progressive loss of supporting structures, and I saw many fairly good prospective dental ridges slowly melt away and lead to extremely difficult complete denture cases. I think any dental practice can be carried to extremes, and in the situation just described, it was overdone. Present knowledge and practice of periodontal therapy along with splinting of the teeth would have prevented the outcome of many of the cases. However, the ability to judge when to attempt to save and when not to is not possessed by every practitioner. I am sure I am making some mistakes right now.

In your letter you state, "In contrast, I have heard many clinicians say that the amount of resorption of the alveolar process following the removal of the teeth is the same regardless of the amount or type of periodontal involvement present." That is probably true provided the patient lives long enough. However, prosthodontics has advanced also, and today we have the tools to retard the rate of resorption, or at least we think we have—not in all patients but in most. We feel that we have learned a great deal about nutrition and can see, clinically and visually, the improvement in appearance of oral tissues when full and proper attention is given to food intake along with dietary supplements. Present knowledge of the importance of proper centric relation accompanied by balancing occlusions and removal of occlusal interferences has aided in preservation of ridges. Of course, there are some patients with ridges, very few however, that continue to show resorption regardless of continuous follow-up treatment and care. These may be the same patients who would not respond satisfactorily to periodontal care.

I do not think that in our lifetime, mine anyway, we will be in a position to let up in our search for improvement of denture service. It will be many generations before periodontal care of the right sort will be available to everyone. Until that day comes, many people will neglect their teeth until they become edentulous. Dr. Behrman's work is directed toward helping the edentulous patient.

As a point of information, the Editorial Council determines policies of the JOURNAL and does very little actual screening or editing. That is left to Dr. Boucher, who in turn is answerable to the Editorial Council.

I am glad you wrote the letter. Your point is well taken and shows that we have a prominent periodontist among our readers.

Sincerely,

LOUIS S. BLOCK, D.D.S.

NEWS AND NOTES

MEETINGS

American Association of Audio Analgesia, New York Academy of Sciences, New York, Oct. 9, 1961.

Eleventh Annual Instrument Symposium and Research Equipment Exhibit, Bethesda, Md., Oct. 9 to 12, 1961.

American Academy of Maxillofacial Prosthetics, Benjamin Franklin Hotel, Philadelphia, Pa., Oct. 11 to 13, 1961.

American Denture Society, Drake Hotel, Philadelphia, Pa., Oct. 13 and 14, 1961.

American Dental Society of Anesthesiology, Statler-Hilton Hotel, New York, Oct. 13 to 15, 1961.

American Society of Dentistry for Children, 34th Annual Meeting, Bellevue-Stratford Hotel, Philadelphia, Pa., Oct. 13 to 15, 1961

American Academy of Implant Dentures, Third Annual International Seminar on Implants in Dentistry, Philadelphia, Pa., Oct. 13 to 15, 1961. For further information and application write to Dr. A. Norman Cranin, Chairman, The American Academy of Implant Dentures, 2120 Ocean Ave., Brooklyn 29, N. Y.

The American Association of Hospital Dental Chiefs, to be held at the Philadelphia General Hospital, Philadelphia, Pa., Oct. 16, 1961.

The American Academy of Periodontology, 47th Annual Meeting, to be held on board the M. S. Bergensfjord sailing from Philadelphia on Oct. 20, 1961, to Bermuda and returning to Philadelphia on Oct. 25. For further information write to Caribbean Cruise Lines, Suite 301, Roeper Bldg., Miami 32, Fla., to the attention of Mr. E. M. Baskette.

The American Institute of Oral Biology, 18th Annual Meeting, Palm Springs, Calif., Nov. 6 to 10, 1961.

Greater New York Academy of Prosthodontics, Columbia University, New York, December, 1961.

The American Academy of Crown and Bridge Prosthodontics, Conrad Hilton Hotel, Chicago, Ill., Feb. 17 and 18, 1962.

The American Academy of Restorative Dentistry, Conrad Hilton Hotel, Chicago, Ill., Feb. 17 and 18, 1962.

The Southeastern Academy of Prosthodontics, Tutwiler Hotel, Birmingham, Ala., April 13 to 15, 1962.

The Academy of Denture Prosthetics, Broadmoor Hotel, Colorado Springs, Colo., April 29 to May 4, 1962.

American Society of Oral Surgeons, to be held at the Royal College, London, England, July 1 to 4, 1962. For further information dentists and physicians in the United Kingdom and Europe may write to Dr. Terence Ward, Royal College of Surgeons, Lincoln's Inn Fields, London, W.C. 2., England; those in the United States and other countries should write to Mr. D. C. Trexler, American Society of Oral Surgeons, 840 North Lake Shore Dr., Chicago, Ill.

ANNOUNCEMENTS

Reprints of the second edition of the *Glossary of Prosthodontic Terms* are now available. Prices: 1 to 20 copies, fifty cents each; 20 to 49 copies, forty cents each; 50 to 99 copies, thirty-five cents each; 100 or more copies, twenty-five cents each. Orders for less than 100 will be mailed prepaid; orders for 100 or more will be sent shipping charges collect. Cash, check, money order, or institution purchase order *must* accompany the order for reprints. Orders will not be filled otherwise. Address: Glossary Reprints, 3939 Old Brownsboro Rd., Louisville 7, Ky.

Reprints of Reports Nos. 1 and 2, "Principles, Concepts, and Practices in Prosthodontics," may be obtained by writing Dr. W. Les Warburton, Secretary-Treasurer, The Academy of Denture Prosthetics, 807 Medical Arts Bldg., Salt Lake City 11, Utah. The price is twenty-five cents for both, with a 20 per cent discount allowed on purchases of 20 or more. Cash, check, or purchase order *must* accompany the order.

NATIONAL DENTAL LABORATORY WEEK

National Dental Laboratory week will be observed Sept. 23 to 30, 1961. This week will be celebrated as part of the Tenth Anniversary of the National Association of Dental Laboratories, which is being observed this year, and will mark the "coming of age" of the ethical dental laboratories of the United States. National Dental Laboratory week will come just before the NADL Annual Meeting in Chicago, Oct. 3 to 7, 1961, at which the announcement of the new dental laboratory accreditation program being developed with the American Dental Association is expected to be presented.

In the 10 years of its history, the National Association of Dental Laboratories has been building closer liaison with the profession of dentistry in its service to the dental prescription or authorization, and this year is hoped to mark the culmination of a great deal of work, planning, and development which has included, in cosponsorship with the American Dental Association, the national program of certification for dental laboratory technicians.

The Dentists' Supply Company of New York has established two tuition scholarships for the school year 1961-1962 through a special grant to the Fund for Dental Education. Two additional scholarships will be established for the academic year 1962-1963. The scholarships are intended to encourage young men and women to select dental laboratory technology as a lifetime career and to assist them in acquiring the necessary training.

Applications are available from the Fund for Dental Education, The Dentists' Supply Company, or the National Association of Dental Laboratories.

Readers of THE JOURNAL OF PROSTHETIC DENTISTRY are invited to present lectures, projected conferences, table clinics, and demonstrations on any aspect of the field of dentistry before the Federación Odontológica de Centro América y Panamá, Jan. 21 through 26, 1962, in Panama.

For further information write to Dr. Alfredo H. Berguido, Apartado 4115, Panamá, República de Panamá.

Tufts University, Department of Periodontology, announces the establishment of a registry of gingival disease. The increasing awareness of the importance of gingival disease has created the need for a clearing house for the histopathologic evaluation of diagnostic and treatment problems. Practitioners are invited to submit gingival biopsies for diagnosis. Additional pertinent information will be provided by the registry regarding the nature of individual cases. Permanent files will be maintained for follow-up case study. There is no charge for this service.

Necessary forms and mailing containers will be sent on request by writing to Tufts University, School of Dental Medicine, 136 Harrison Ave., Boston 11, Mass.

WORKSHOP ON ADHESIVE RESTORATIVE MATERIALS

The National Institute of Dental Research of the U. S. Public Health Service has announced that a grant of $9,600 has been awarded to Indiana University, School of Dentistry, to organize an initial workshop on the development of an adhesive restorative material. The chairman for this workshop will be Prof. Ralph W. Phillips of Indiana University, School of Dentistry, and the co-chairman Dr. Gunnar Ryge of Marquette University, School of Dentistry. The workshop will be held at Indianapolis, Ind., Sept. 28 and 29, 1961.

The participants in this initial workshop will be by invitation only and will represent the various basic and applied sciences upon which the development of a truly adhesive dental material will depend. Experts in the fields of tooth structure composition, surface and polymer chemistry, and test methods for measuring adhesion have already been selected.

It has long been recognized that one of the dental research areas having a high priority for expanded investigation is that concerned with the development of a restorative material or cement that will adhere to tooth structure. This will be the first attempt to bring together interested and qualified people in the profession, industry, and universities to explore the current knowledge and to establish recommendations for future fruitful research.

The proceedings of this 2 day workshop will be transcribed in entirety and published.

The Philadelphia County Medical Society is establishing a library of health education literature for use by the public as well as physicians.

The library will consist of pamphlets and booklets on all health topics. These will include socioeconomic factors, health and safety, medical practice, diseases and disease control, and miscellaneous subjects in the health field.

In addition, the library will contain books on health education and educational techniques such as radio and television. Film catalogues and resource agencies for more material also will be included.

The public, science and medical students, physicians, and others in the health field will have access to the library, which will be located in the Medical Society's building at 301 South Twenty-first St., Philadelphia, Pa. It will be used as a resource library for the Medical Society's speakers' bureau.

The library is being established through the efforts of the Medical Society's public relations committee, headed by Dr. Edward G. Sharp.

Contributions of pamphlets and resource catalogues for the library may be sent to Bette Metzler, Ball Associates Public Relations Agency, 845 North Broad St., Philadelphia 23, Pa.

The third edition of the annual directory and bibliography of the National Institutes of Health has been published by the U. S. Public Health Service.

The publication is intended for reference use by research workers in the biomedical sciences inside and outside the Federal government. It presents the broad outlines of NIH structure, names the professional staff, and lists more than 1,600 scientific and technical papers deriving from the NIH program of direct research—laboratory and clinical—during 1960. This number represents a 70 per cent increase in published papers since 1956.

Designed to increase the usefulness of the volume are two indexes: one lists staff members and authors; the other, a subject index, reflects the scope of NIH research and provides quick reference to major and subordinate research areas. These areas covered the vast extent of problems that concern biomedical scientists—from the biochemistry within the human cell to the causes and control of the degenerative diseases and the physiologic and psychologic aspects of aging.

Copies of the publication are available from the Public Information Section, Office of Research Information, National Institutes of Health, Bethesda, Md.

FELLOWSHIPS AND GRADUATE STUDY

Albert Einstein College of Medicine, Postgraduate Dental Program, will sponsor courses in anesthesiology, endodontics, oral pathology, oral surgery, orthodontics, periodontics, pharmacology, clinical photography, and prosthetics during the academic year 1961-1962. All courses are designed to be integrated into the general dental practice.

For further information and application write to Director, Postgraduate Dental Program, Albert Einstein College of Medicine, Eastchester Rd. and Morris Park Ave., Bronx 61, N. Y.

Boston University, School of Medicine, Division of Graduate Studies, Department of Stomatology, offers opportunities for graduate study in oral surgery, orthodontics, prosthetics, endodontics, and oral pathology. These courses are of 1 to 2 academic years' duration. For further information write to Department of Stomatology, Boston University, School of Medicine, 80 East Concord St., Boston 18, Mass.

Grasslands Hospital, Valhalla, N. Y., in affiliation with the School of Dental and Oral Surgery of Columbia University, announces the establishment of new residency programs in prosthodontics and oral surgery.

These programs are of 2 years' duration. They lead to a certificate of training awarded by Columbia University in addition to the certificate for resident training awarded by Grasslands Hospital.

For further information and application write to Director, Grasslands Hospital, Valhalla, N. Y.

Loyola University, Chicago College of Dental Surgery, is offering a research and teacher training program in oral biology. This is under a teacher training grant from the National Institutes of Health. It is designed for candidates who desire a teacher's career in basic sciences or in clinical subjects. The stipends are up to $5,000 per year, and the program can lead to an advanced degree.

For further information and application write to Dr. Harry Sicher, Director, Loyola University, Chicago College of Dental Surgery, 1757 West Harrison St., Chicago 12, Ill.

Graduate trainingship grant awards through the National Institute of Dental Research are available to qualified individuals in the fields of medicine, dentistry, speech, and special education.

The course (Oct. 9 to 12, 1961) concerns the habilitation/rehabilitation program of persons with oral-facial-speech handicaps.

For further information write to Robert T. Millard, Program Director, Lancaster Cleft Palate Clinic, 24 North Lime St., Lancaster, Pa.

POSTGRADUATE COURSES

The University of Alabama, School of Dentistry, will present the following refresher courses:

Dental Assisting: Dr. Paul E. Hammons, Gertrude M. Sinnett, and associates, Oct. 28 and 29, 1961.

Complete Dentures: Dr. John J. Sharry, Nov. 4 to 6, 1961.

Clinical Oral Surgery: Dr. Robert B. Shira, Nov. 11 to 13, 1961.

Root Canal Therapy: Dr. Adeeb E. Thomas, Nov. 25 to 27, 1961.

For further information and application write to the Director, Refresher Course Program, University of Alabama, School of Dentistry, 1919 Seventh Ave., S., Birmingham 3, Ala.

Boston University, School of Medicine, Division of Graduate Studies, Department of Stomatology, announces the following postgraduate courses:

Esthetics in Restorative Dentistry: Dr. Charles Pincus, Oct. 20 and 21, 1961.

Occlusal Adjustment: Dr. Bernard S. Chaikin, Dr. Henry M. Goldman, Dr. Gerald M. Kramer, Dr. William Pendergast, Dr. Irving Romanow, Dr. J. David Kohn, Dr. David J. Baraban, Dr. Leo Talkov, Dr. David V. Berry, and Dr. Jack Bloom, Oct. 30 to Nov. 3, 1961.

Periodontal Therapy: Dr. Henry M. Goldman, Dr. Bernard S. Chaikin, Dr. Gerald M. Kramer, Dr. William Pendergast, Dr. Irving Romanow, Dr. Jack Bloom, and associates, Nov. 6 to 10, 1961.

Endodontics: Dr. Herbert Schilder, Nov. 13 to 17, 1961.

Fixed Bridge Prosthesis: Dr. Leo Talkov, Dr. David J. Baraban, and Dr. Lloyd Warshauer, Nov. 27 to Dec. 1, 1961.

Periodontal Pathology: Dr. Henry M. Goldman and Dr. Jack Bloom, Jan. 22 to 26, 1962.

The Use of Ultrasonics in Periodontal Therapy: Dr. Henry M. Goldman, March 17, 1962.

Periodontal Therapy: Dr. Henry M. Goldman, Dr. Bernard S. Chaikin, Dr. Gerald M. Kramer, Dr. William Pendergast, Dr. Jack Bloom, and associates, March 19 to 23, 1962.

For further information write to Director of Postgraduate Studies, Department of Stomatology, Massachusetts Memorial Hospitals, 750 Harrison Ave., Boston 18, Mass.

The First District Dental Society, a component of the Dental Society of the State of New York and the American Dental Association, announces the following postgraduate courses:

Preparation of Teeth for Jackets for Abutment Purposes: Dr. I. Franklin Miller, Oct. 5 to 7, 1961.

Newer Concepts in Restorative Dentistry: Dr. Alexander Leff, Oct. 18 and 19, 1961.

Occlusal Adjustment—Integration Into the Practice of Dentistry: Dr. Julius N. Obin, Oct. 18, 1961.

Oral Dynamics: Dr. John T. McSweeney, Oct. 19 to 21, 1961.

Horizontal Pinsplinting of Anterior Teeth: Dr. A. J. Feldman and Dr. Carl Sanell, Oct. 27 and 28, 1961.

For further information and application write to the Postgraduate Education Program, First District Dental Society, Statler Hilton, New York 1, N. Y.

New York University announces courses for 1961-1962 to be given in fixed partial prosthesis and in complete oral rehabilitation. Both courses involve practical chair work, lectures, and demonstrations. "Fixed Partial Prosthesis" utilizes elastic impression materials. The course will be given on Friday afternoons for 16 weeks beginning January, 1962, by Prof. Edward G. Kaufman.

"Complete Oral Rehabilitation" will be given every Friday for 32 weeks beginning October, 1961. The course covers full mouth treatment utilizing axis registrations and detailed occlusal study. Enrollment is limited, and acceptance is made only after personal interview. Instructors are Prof. David H. Coelho, Prof. Eugene A. Rothschild, and Prof. Albert Zola.

For further information and application write to Director, Postgraduate Division, New York University, College of Dentistry, 421 First Ave., New York 10, N. Y.

The Ohio State University, College of Dentistry, announces the following postgraduate courses:

Complete Denture Prosthodontics: Dr. Carl O. Boucher, Oct. 2 to 6, 1961.

General Anesthesia: Dr. Morgan L. Allison, Nov. 13 to 17, 1961.

Oral Surgery: Dr. Morgan L. Allison, Nov. 27 to 29, 1961.

Hospital Management for Dental Procedures: Dr. Morgan L. Allison and Dr. Bernard S. Snyder, Jan. 22 to 24, 1962

Clinical Periodontics: Dr. John R. Wilson and Dr. William V. Walton, Jan. 25 to 27, 1962.

A Refresher Course in Dental Hygiene: Dr. Consuelo Wise and Dr. John R. Wilson, Jan. 29 and 30, 1962.

Crown and Bridgework: Dr. Thomas F. McBride and Dr. Alfred C. Long, Jan. 31 to Feb. 2, 1962.

Pedodontics and Interceptive Orthodontics: Dr. Lyle S. Pettit and Dr. Benjamin H. Williams, Feb. 5 to 9, 1962.

Complete Denture Prosthodontics: Dr. Carl O. Boucher, Feb. 26 to March 2, 1962.

Removable Partial Denture Prosthodontics: Dr. Victor L. Steffel, March 5 to 9, 1962.

For further information and application write to the Ohio State University, College of Dentistry, 305 West Twelfth Ave., Columbus 10, Ohio.

The University of Pennsylvania, School of Dentistry, announces the following postgraduate courses:

Endodontics: Dr. Louis I. Grossman and associates, Oct. 4 (1 day per week for 11 weeks), 1961.

Part III of Practical Procedures in Oral Rehabilitation: Dr. Ernest R. Granger, Dr. William Maxwell, and Dr. Robert Simpson, Oct. 9 to 13, 1961

Dental Assisting: Dr. Virginia R. Park and associates, Oct. 23 (2 evenings per week for 55 sessions), 1961.

Ultrasonics for the General Practitioner: Dr. John H. Stine and associates, Oct. 28, 1961.

Dentistry for Handicapped Children: Dr. Manuel M. Album and associates, Nov. 20 to 23, 1961.

Dermatologic Lesions with Oral Manifestations: Dr. Jens J. Pindborg of Copenhagen, Denmark, Nov. 27 and 28, 1961

The Use of Ultrasonics in Periodontia: Dr. Henry M. Goldman and Dr. D. Walter Cohen, Dec. 16, 1961.

Oral Pathology: Dr. Lionel Gold and associates, Jan. 6, 1962.

Periodontal Histopathology: Dr. Henry M. Goldman, Dr. D. Walter Cohen, and Dr. Frederic M. Chacker, Jan. 8 to 12, 1962

For further information and application write to Director of Postgraduate Courses, University of Pennsylvania, School of Dentistry, 4001 Spruce St., Philadelphia 4, Pa.

Tufts University, School of Dental Medicine, announces the following postgraduate courses:

A Demonstration Course in Full Upper and Lower Dentures: Dr. Victor H. Sears, Sept. 29 to Oct. 1, 1961.

Dental Care for the Handicapped Child: Dr. M. Michael Cohen and staff, Oct. 2 to 5, 1961.

Cancer of the Oral Cavity and Salivary Glands: Dr. Gerald Shklar, Dr. Irving Meyer, and staff, Oct. 12 (for 6 Thursdays), 1961.

New Concepts for Inlay Construction: Dr. R. Sheldon Stein, Nov. 7 and 8, 1961.

Hospital Management of the Dental Patient: Dr. Richard Taylor and Dental Department, Feb. 7 to 9, 1962.

Crown and Bridge Design and Construction: Dr. Frank A. Eich, Feb. 15 and 16, 1962.

A Participation Course in Applied Anatomy of the Head and Neck: Dr. Alton D. Brashear and Dental Department, Feb. 28 to March 2, 1962.

Orthodontic Principles of Interest to the General Practitioner: Dr. Shapiro, Dr. Mendeloff, and Dr. Field, Feb. 28 to April 4 (6 Wednesdays, all day), 1962.

Complete Mouth Rehabilitation Through Fixed Partial Denture Prosthodontics: Dr. Harry Kazis and Dr. Albert J. Kazis, Feb. 28 (for 6 Wednesday afternoons and evenings), 1962.

The Diagnosis, Management and Therapy of Lesions of the Oral Mucosa: Dr. Philip McCarthy, Dr. Francis P. McCarthy, and Dr. Gerald Shklar, March 7 to April 25 (8 consecutive Wednesdays), 1962.

Surgical Pathology of the Mouth and Jaws: Dr. Irving Meyer, Dr. Gerald Shklar, and staff, March 8 to May 10 (8 Thursdays), 1962.

Prosthetic Procedures for the Periodontal Problem: Dr. Louis Alexander Cohn, April 5 to 7, 1962.

A Special Participation Course in Periodontology: Dr. Irving Glickman and department staff, April 9 to 13, 1962.

Clinical Adjustment of the Occlusion: Dr. Bernard Jankelson, May 2 to 4, 1962.

Minor Oral Surgery: Dr. Richard Taylor and staff, May 8 to 10, 1962.

Children's Dentistry for the General Practitioner: Dr. Sidney B. Finn, May 21 to 23, 1962.

For further information and application write to Dr. L. Walter Brown, Jr., Director, Postgraduate Refresher Courses, Tufts University, School of Dental Medicine, 136 Harrison Ave., Boston 11, Mass.

Yeshiva University, Albert Einstein College of Medicine, Department of Dentistry, announces the following postgraduate courses:

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Prosthodontics (Oro-facial Prosthetics): Dr. L. Rosenthal, Dr. M. Pleasure, Dr. S. Lane, and Dr. M. Ivker, Nov. 30 and Dec. 1, 1961

For further information and application write to Director, Postgraduate Dental Division, Yeshiva University, Albert Einstein College of Medicine, Eastchester Rd. and Morris Park Ave., Bronx 61, N. Y.

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